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Artificial Reefs

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On the cover: An artificial reef of used tires.

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A Review of the South Pacific Tuna Baitfisheries: Small Pelagic Fisheries Associated with Coral Reefs

P. DALZELL and A. D. LEWIS

ABSTRACT—A review is given of current information concerning small pelagic fishes exploited for tuna bait in the South Pacific. These fishes are usually caught over or near coral reefs using light attraction and lift nets. The most common and widespread species are anchovies (Engraulidae), sprats (Clupeidae), silversides (Atherinidae), and herrings (Clupeidae). Recorded yields ranged from 0.5 to 2.6 t/km², and methods are described to estimate potential yields empirically in the absence of catch data. Environmental effects on small pelagic fish prodution are discussed, and evidence is presented to suggest that rainfall markedly affects stolephorid anchovy production. Some species of small pelagic fish, such as Selar *spp.,* Decapterus *spp., and* Herklotsichthys *sp., have been fished traditionally by artisanal fishermen, but anchovy and sprat stocks were probably unexploited prior to pole-and-line tuna fishing in the South Pacific.*

Introduction

The small pelagic or mackerel-like and herring-like fishes of the South Pacific islands (Table 1) have been exploited both by artisanal fishermen as food fish and by pole-and-line tuna fishing vessels for live bait. Exploitation by tuna vessels is a relatively recent phenomenon and constitutes probably the only truly industrial-scale fisheries that have operated within the inshore coastal waters of the South Pacific islands. Not all these pole-and-line tuna fisheries have maintained operations. Examples of these are the fleets that were based at Palau in the Western Caroline Islands (Muller, 1976; Wilson, 1977) and in Papua New Guinea (PNG) (Lewis et al., 1974; Dalzell and Wankowski, 1980). Pole-and-line tuna fishing (and hence, baitfishing) continues to be pursued in the Solomon Islands (Evans and Nichols, 1985; Tiroba[1]), Fiji (Lewis et al., 1983; Sharma[2]), and Kiribati (McCarthy, 1985; Ianelli, 1988).

Investigations into the biology, population dynamics, and fisheries dynamics of past and present tuna baitfisheries represent the major studies of small pelagic resources in the South Pacific region, although some investigations of small pelagic resources have also been made around New Caledonia in the absence of an established pole-and-line fishery (Conand, 1988). The short-term survey fishing of the South Pacific Commission Skipjack Survey and Assessment Programme (SSAP) survey resulted in a wide ranging set of samples of small pelagic fishes taken in most of the states and territories within the South Pacific (Kearney, 1982). Artisanal fisheries which certainly exploit small pelagic resources remain for the most part unstudied.

All of the baitfisheries detailed above and many of the artisanal fisheries that catch small pelagics are adjacent to coral reefs. These fisheries are not, however, normally perceived as reef fisheries per se. Assessment of the inshore coral reef fishery resources of the South Pacific islands including the small pelagic fishes is timely, given the small agricultural land area of much of the region and the high rates of population increase currently estimated overall at 2.5 percent (Connell, 1984). In this paper, we review the available data on inshore reef-associated small pelagic resources. The characteristics of the resources and the fisheries are described and attempts are made to give some estimate of potential yields.

Table 1.—Species considered as small pelagics in the context of the South Pacific Region.

Common name	Genus
Anchovies	*Stolephorus*[1] spp., *Thryssa* spp.
Sardines	*Sardinella* spp., *Amblygaster* spp.
Round herrings	*Dussumieria* spp.
Herrings	*Herklotsichthys* spp., *Pelona* spp.
Sprats	*Spratelloides* spp.
Mackerels	*Rastrelliger* spp.
Scads	*Decapterus* spp., *Selar* spp., *Selaroides* spp., *Atule* spp.
Fusiliers	*Pterocaesio* spp., *Caesio* spp., *Gymnocaesio* spp.
Flying fish	Exocoetidae
Half beaks	*Hemiramphus* spp., *Hyporhamphus* spp.

[1]Nelson (1983) has placed the smaller stolephorids such as *Stolephorus heterolobus*, *S. devisi*, *S. punctifer* and *S. purpureus* in a separate genus, *Encrasicholina*. We have maintained the previous reference to avoid confusion.

Fishing Methods

The pole-and-line fishing vessels operating in the South Pacific region also serve as platforms for catching small pelagic baitfish. These are caught by the use of a stick-held dip net, or bouke-ami, assembled and mounted on the pole-and-line vessel (Fig. 1). The baitfish are aggre-

[1]Tiroba, G. K. 1986. Biological studies of exploited baitfish species, *Stolephorus heterolobus* and *Stolephorus devisi* in Western Province, Solomon Islands. Minist. Nat. Resour., Fish. Dep., Honiara, Solomon Isl. Unpubl. rep., 64 p.

[2]Sharma, S. 1988. The Fijian baitfishery. Presented at South Pacific Commission Inshore Fisheries Resources Workshop, Noumea, New Caledonia, March 1988, SPC/Inshore Fish. Res./BP 14. Unpubl. rep., 19 p.

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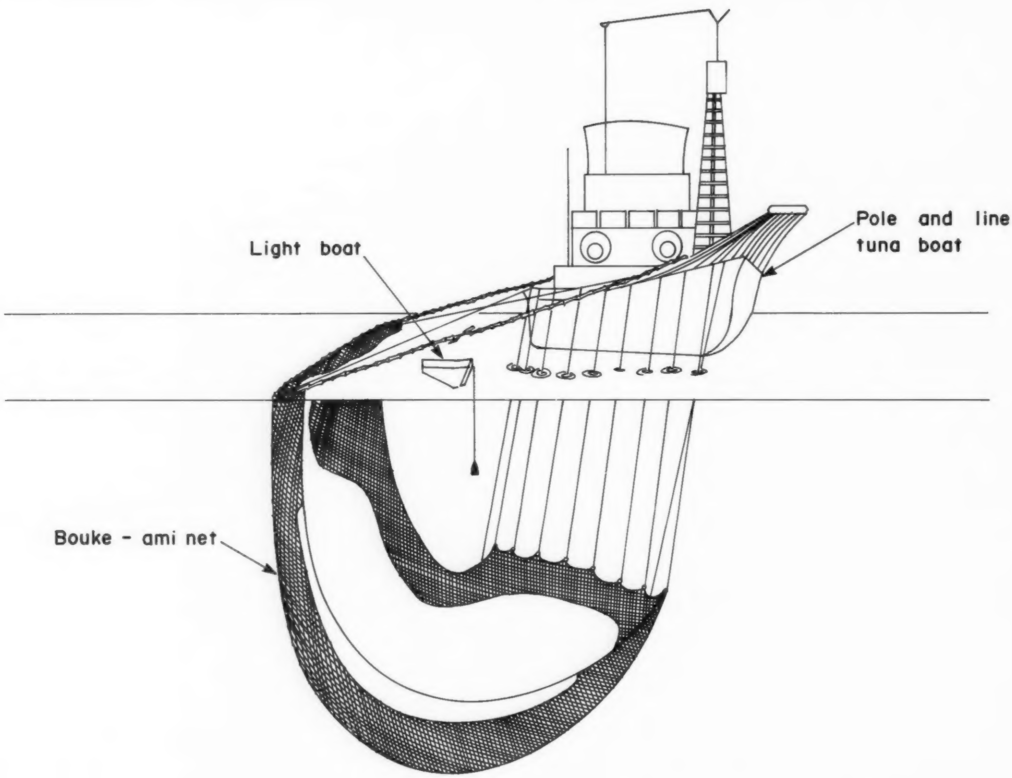

Figure 1.—Operation of a bouke-ami fishing net used to catch small pelagic baitfish; based on FAO (1974) and Muyard (1980).

gated at night around submersible lamps of 1–1.5 kW that are used after dusk. Besides lamps suspended from the vessel itself, other catching stations may be established by using lamps powered by a generator mounted on a small skiff.

During the setting and hauling of the net, the lights are raised to near the surface and dimmed to compact the baitfish schools. Surface illumination may also be employed to draw the fish nearer to the surface. After the net is hauled, the mass of baitfish is concentrated in one section of the net to be brailed into buckets and then emptied into baitwells set in the hull of the pole-and-line vessel.

Distribution and Biogeography of South Pacific Small Pelagics

The term "South Pacific," as defined here, includes the island groups of Micronesia, Melanesia, and Polynesia and does not strictly refer to locations south of the equator (Fig. 2). The nations and territories in the region range from the large land mass of PNG (land area = 460,000 km^2) through medium sized island groups (land area = 10–20,000 km^2) such as Fiji, Vanuatu, and the Solomon Islands, to small islands or atoll clusters (land area = <5,000 km^2) such as Tonga, Kiribati, and French Polynesia. The region extends over 29×10^6 km^2, although total land mass covers only 550,000 km^2, 85 percent of which is contained within PNG (Dahl, 1984).

Springer (1982) has proposed that the South Pacific belongs to a major subunit of the Indo-Pacific biogeographic region. This is because the Pacific Plate, largest of the earth's lithospheric plates, occupies most of the area referred to as the Pacific Basin. The faunal characteristics of the Pacific Plate are a cline of decreasing species diversity in an easterly direction across the Plate and a high degree of endemism within the Plate boundaries. The island groups of Melanesia (PNG, Solomon Islands Vanuatu, and Fiji) and the islands of Tonga are all situated on the Plate margin as are the Western Caroline and Marianas Islands. The remaining island groups of the South Pacific are all located on the Pacific Plate.

Besides "mackerel-like" and "herring-like", the term "small pelagic" here refers to fish which have a maximum weight of 500 g and inhabit the upper surface layer of the water column. The definition of small pelagic fishes in the context of the

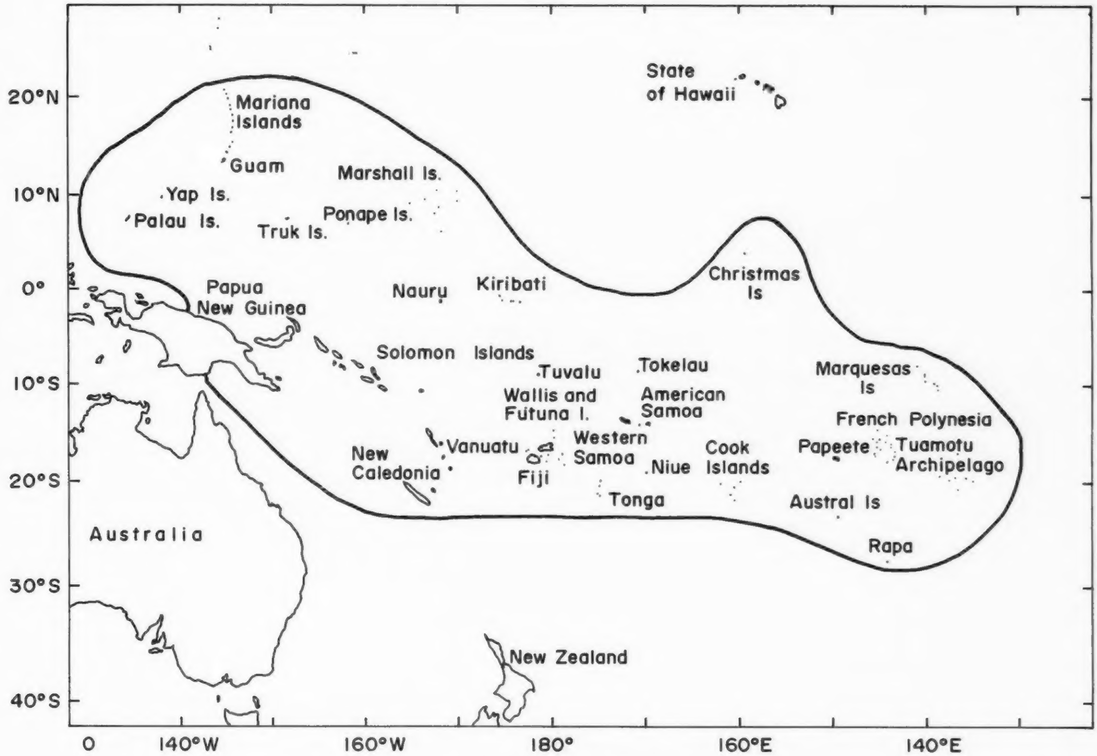

Figure 2.—The South Pacific Region as defined in the text.

Table 2.—Number of principal small pelagic baitfishes at different locations within the South Pacific region. Source: Lewis et al. (1983)

Country/ Territory	Anchovies	Sardines & sprats	Silver-sides	Scads	Fusiliers	Mackerel	Total	Distance from 130°E (km)	L_n N
PNG	8	14	7	7	6	4	46	2.070	3.83
Solomon Islands	5	9	6	6	6	3	35	3.106	3.56
Vanuatu	3	6	2	4	2		17	4.659	2.83
New Caledonia	5	8	4	5	6	1	29	4.400	3.37
Fiji	7	10	5	5	7	3	37	3.694	3.61
Tonga	2	6	2	4	0	1	15	6.730	2.71
Wallis/Futuna	1	4	3	2	1	1	12	5.954	2.48
Western Samoa	6	7	2	2	2	2	21	6.885	3.04
American Samoa	7	5	1	0	0	1	14	7.248	2.64
Palau	5	6	3	3	3		20	.518	3.00
Yap	3	2	2	0	1		8	.984	2.08
Truk	0	4	2	1	0		7	2.589	1.95
Ponape	4	5	5	4	2	1	21	3.365	3.04
Kosrae	5	3	4	2	0		14	3.883	2.64
Marshall Islands	0	3	2	1	0	1	7	4.400	1.95
Kiribati	0	5	2	3	4	1	15	5.436	2.71
Tuvalu	0	1	2	3	1		7	5.798	1.95
Tokelau	1	1	1	0			1	7.041	1.10
Cook Islands	0	1	3	2			6	8.542	1.79
Society Islands	3	2		3			8	9.319	2.08
Marquesa Isl.	0	1		4			5	10.923	1.61
Tuamotu Islands	0	1		2			3	10.613	1.10
N.E. Qld (Aust.)	6	5		1			12	2.330	2.48

South Pacific is given by the summary in Table 1. The occurrence of different small pelagic baitfish species in SPCTP baitfish hauls in the South Pacific region is documented in Lewis et al. (1983). This has been summarized by family in Table 2. The long. 130°E line was taken as a convenient western boundary of the South Pacific region. A functional regression of the logarithm of the number of small pelagic species vs. distance in an easterly direction from long. 130°E had a highly significant negative slope (Fig. 3). This analysis supports the suggestion of Springer (1982) that species diversity declines in an easterly direction across the Pacific Plate. Allen (1975) found a similar relationship for pomacentrid fishes in the South Pacific region.

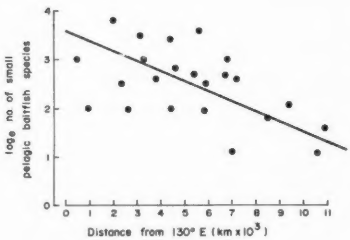

Figure 3.—Logarithms of number of small pelagic baitfish species vs. distance east of the long. 130°E line.

The generalized distribution of small pelagic fishes on both coralline and non-coralline shelf areas has been reviewed by Dalzell and Ganaden (1987). (This scheme is somewhat compressed in most Pacific Island situations with their very narrow continental shelves.) Within the coastal zone are found the big-eye scads, anchovies, clupeoids, and half-beaks. The exception amongst the anchovies is *Stolephorus punctifer*, a stenohaline species which prefers neritic and oceanic waters (Hida, 1973). Dalzell (1984a) has shown that the catch per effort and abundance of *S. punctifer* in PNG is inversely correlated with annual rainfall (see further below). The fusiliers (i.e., *Caesio* and related genera) are included since their distribution is determined largely by the extent of coral cover which is generally associated with shallow (<30 m depth) coastal water. Studies of lightly exploited reef-fish populations on the Australian Barrier Reef (Williams and Hatcher, 1983) and a heavily exploited small island fringing reef in the Philippines (Alcala and Gomez, 1985) have shown that fusiliers formed the largest component of the fish biomass. Further, fusiliers form 75 percent of all fish captured by muro-ami or drive-in nets on Philippine coral reefs and account for 99 percent of the small pelagic fishes caught by this method (Dalzell, unpubl. data).

Further offshore are found the mackerels (*Rastrelliger* spp.), although according to Druzhinin (1970), there appears to be a differential distribution between *R. brachysoma* and *R. kanagurta*, the former being more common in nearshore waters. Ranging between the neritic and truly oceanic areas are the roundscads (*Decapterus* spp.). Although these species are generally caught around shelf areas, they have also been captured around fish aggregating devices in the Celebes Sea in >5,000 m of water, well away from the shelf zone (K. L. Yamanaka, Univ. Brit. Col., personal commun., 1987) and are often caught by purse seiners in the South Pacific operating at great distances from land (Gillett, 1987). Similarly, flying fishes inhabit both inshore coastal waters and the open ocean.

Species Composition of Small Pelagic Baitfish Catches

The SSAP surveys for small pelagic tuna baitfish in the South Pacific region were carried out between 1977 and 1980. These surveys suggested that five species, *Spratelloides delicatulus*, *Stolephorus devisi*, *S. heterolobus*, *Herklotsichthys quadrimaculatus*, and *Atherinomorus lacunosa*, were both widespread and abundant. Other common species were *Hypoatherina ovalaua*, *Selar crumenophthalmus*, *Amblygaster sirm*, *Spratelloides gracilis*, and *Stolephorus punctifer*.

Long-term sampling of baitfish catches at Palau, PNG, Solomon Islands, Kiribati, and Fiji has resulted in more detailed information on the composition of these small pelagics at specific sites. A summary of the results of these studies is given in Table 3. At Palau, PNG, and the Solomon Islands, the dominant species caught are stolephorid anchovies at 50–90 percent of the landings. The sprats form another important species grouping, particularly at the Ysabel Passage, PNG, where *S. gracilis* averages 36 percent of catches.

Table 3.—Species composition of sustained baitfish catches in the South Pacific region as determined by catch sampling.

Species	Fiji	PNG	Solomon Isl.	Palau[1]	Kiribati	New Caledonia
Sprats	23.4	18.1	11.1		40.5	3.7
Sardines	15.8	5.4	1.0		27.8	15.1
Herring	14.6		1.2		17.7	
Silversides	4.3	1.2	0.3		5.3	0.3
Mackerels	6.4	1.1	0.3			
Cardinals[2]	16.6	1.6	0.2		0.8	
Anchovies	10.4	62.6	72.7	91.0		62.5
Fusiliers		7.7	0.5			
Scands		1.4				
Others	9.1	0.9	13.0	9.9	8.0	18.4

[1]No details of other species in catch given by Muller (1976).
[2]Demersal fishes; consist mainly of *Rhabdamis* spp.

Unlike the sites listed above, baitfish catches in Fijian waters are dominated by seven species or species groupings, with stolephorid anchovies comprising only 13 percent of the catch. At Kiribati, the dominant baitfish species are *Spratelloides delicatulus*, *Amblygaster sirm*, and *Herklotsichthys quadrimaculatus* which together contribute up to 86 percent of the catch. The herring, *H. quadrimaculatus*, which comprises about 7 percent of the catch, is also an important component of artisanal beach seine catches in Kiribati (Kleiber and Kearney, 1983; Ianelli, 1988).

In neighboring Southeast Asia, roundscads and sardines make major contributions to small pelagic fish catches. The only sardines of any significance in South Pacific small pelagic catches are *Amblygaster sirm* and *Sardinella marquesensis*. Interestingly, *A. sirm* is the most important sardine caught by fishermen in the Philippines and accounts for 8.5 percent of all small pelagic landings (Dalzell et al., In press). Nearshore artisanal gears in the Philippines and Indonesia take predominantly stolephorid anchovies and sardines (Dudley and Tampubolan, 1986; Corpuz and Dalzell[3]). Sardines and anchovies are also major components of large liftnet fisheries using light attraction in the Philippines, although roundscads also make significant contribution to catches (Corpuz and Dalzell[3]).

Some mention should also be made to the Hawaiian live baitfishery for the nehu, *Stolephorus purpureus*. Unlike the South Pacific baitfisheries, nehu are caught in Hawaii both by day and, rarely, by night (night fishing has not occurred in about the last 5 years. Day fishing is done with a seine in turbid inshore waters). South Pacific baitfisheries rely entirely on night baitfishing, although attempts at daylight fishing were made in PNG in the initial year of operations during 1970 (Lewis, 1977); daylight fishing operations were also carried out by the SSAP. In Hawaii, roughly 97 percent of the total bait catch

[3]Corpuz, P., and P. Dalzell. 1988. A summary of the catch, fishing effort data and species composition collection by the DA/BFAR-ICLARM Small Pelagics Management Project. Dep. Agric., Bur. Fish. Aquat. Resour., Int. Cent. Living Aquat. Resour. Manage. Unpubl. rep., 114 p.

comprises *S. purpureus*. Also caught in the baitfishery are *S. delicatulus* and *A. lacunosa* (Uchida, 1977). A relatively large literature exists on *S. purpureus* biology and fisheries; key references include Nakamura (1970), Struhsaker and Uchiyama (1976), and contributions in Shomura (1977) and Clarke (1987; In press).

Catches, Yields, and Biomass of South Pacific Small Pelagic Baitfishes

Time series of catch and fishing effort data are available for the PNG, Solomon Islands, Fiji, and Palau baitfisheries. At all locations, effort can be expressed as boatnights or number of nightly fishing operations by the pole-and-line vessels on an annual basis. A better index of catch per effort (C/f) would be catch per haul. However, effort data (haul numbers) have not been collected consistently at all locations throughout the history of the fisheries. Plots of the relationships of catch vs. effort are shown for the different baitfisheries in Figure 4. Apart for the Palau fishery, the data are best fitted with a straight line forced through the mean of the scatters and the origin.

One interpretation of the apparent linearity of the catch-effort relationship of the baitfisheries is that effort and yields could be increased appreciably. However, the various scatters of points refer to total catch and not individual component species. In the case of the Palau fishery which was comprised almost entirely of a single species, *S. heterolobus*, C/f was markedly reduced at the highest levels of fishing effort (Fig. 4). Further, the catch rates of stolephorid anchovies in northern PNG also appeared to be inversely correlated with fishing effort. Surplus production models of the Schaefer and Fox type could be fitted to the PNG and Palau data (Muller, 1976; Dalzell, 1984b); however, as shown later, environmental effects may be more closely linked to fluctuations of C/f than changes in fishing effort.

In the Ysabel Passage baitfishery of northern PNG, sampling records extend over 14 years, from 1972 to 1973, 1976 to 1981 (Dalzell, 1984b), and again during 1985 (Dalzell, 1986). In the early years of the fishery, species other than *S. heterolobus*, *S. devisi*, and *S. gracilis* comprised about 5 percent of the total catch. By 1976, these other species, comprising mainly Clupeidae, Caesionidae, Atherinidae, and Carangidae, had risen to 10 percent of the catch and continued rising to 30 percent by 1981 (Table 4). Between 1982 and 1984, there was a cessation of fishing activities, which resumed in 1985. Other species comprised 25 percent of the catch during 1985. Such changes are not apparent from simple catch and effort data and may indicate that levels of fishing effort are such that they induce major fluctuations in the biomass and hence, catch rates of the principal species, *S. heterolobus*, *S. devisi*, and *S. gracilis*.

Table 4.—Annual percentage species composition for the Ysabel Passage baitfishery, 1972-1973, 1976-1981, and 1985.

Year	*S. heterolobus*	*S. devisi*	*S. gracilis*	Subtotal	Other spp.
1972	41.9	25.9	26.2	94.0	6.0
1973	41.4	14.6	40.2	96.2	3.8
1976	53.0	30.1	7.0	90.1	9.9
1977	18.9	14.0	56.8	89.7	10.3
1978	41.1	12.8	29.7	83.6	16.4
1979	37.1	28.4	22.2	87.7	12.3
1980	10.2	1.8	65.3	77.3	22.7
1981	20.7	7.7	41.4	69.8	30.2
1985	42.8	11.8	20.7	75.3	24.7

Such large changes in catch composition over the history of a fishery appear to be a characteristic of small pelagic clupeoid fisheries where declines in abundance of one species are offset by partial replacement by other species. Examples of these are the increase of the northern anchovy *Engraulis mordax* with the decline of the California sardine *Sardinops caerulea*; increase of the sardine *Sardinops sagax* with decline of the Peruvian anchoveta *Engraulis ringens*; and the decline of the South African pilchard *Sardinops ocellata* and increase of the anchovy *Engraulis japonicus*. All the examples quoted here are or were major fisheries on upwelling eastern boundary currents (Parrish et al., 1983) whereas the Ysabel Passage baitfishery was a localised small pelagic fishery influenced more by monsoon seasonality (Dalzell, 1984a). Although small pelagic fish populations may demonstrate large natural fluctuations, it is apparent that major changes in species composition and abundance in both instances are possibly induced by fishing pressure. Daan (1980) has reviewed the mechanism responsible for partial species replacement in the above examples and other fisheries.

Table 5.—Average annual yields of small pelagic baitfish at three locations in the South Pacific region.

Location	Area fished (km^2)	Yield (t/km^2 per year)	Sources
PNG[1]	743	1.06	Dalzell (1984b)
Solomon Isl.[2]	806	2.64	Nichols[3]
Palau[4]	300	0.52	Muller (1976)

[1]Based on catches at two baitgrounds, the Ysabel Passage (336 km^2) and Cape Lambert (407 km^2) between 1970 and 1981.
[2]From 120 baitground locations in the Solomon Islands monitored between 1984 and 1986.
[3]Paul Nichols, Fisheries Department, Ministry of Natural Resources, personal commun.
[4]Based on catches at Palau between 1965 and 1974.

Information on yields from the small pelagic baitfisheries is concerned mainly with anchovies, sprats, sardines, and herrings. In only three instances are data suitable to estimate yields directly from observed catches and areas of fishing ground. These are shown in Table 5 and range from about 0.5 to 2.5 t/km^2/year of fishing ground. Munro and Williams (1985) suggest that a figure or 3–5 t/km^2/year is a reasonable estimate of multispecies sustainable yield from coralline shelves.

Muller (1976) analyzed the catch and effort data for the Palau baitfishery and estimated a maximum sustainable yield (MSY) at about 0.48 t/km^2/year for *S. heterolobus*. Dalzell (1984b, 1986) performed similar analyses for the Ysabel Passage and Cape Lambert baitfisheries; the MSY of exploited stocks of *S. heterolobus* and *S. devisi* was about 0.6 t/km^2/year. An analysis of the *S. heterolobus* data alone gave predicted yields of 0.44 t/km^2/year, similar to Muller's (1976) estimate for the Palau stock of the same species. Actual yields of *S. heterolobus* ranged from 0.29 to 0.67 t/km^2/year ($\bar{x}$ = 0.44 t/km^2/year) in Palau and 0.20 to 1.20 t/km^2/year ($\bar{x}$ = 0.49 t/km^2/year) in PNG.

Little is known about the size of standing stocks of small pelagic baitfishes in the South Pacific region. Petits and de

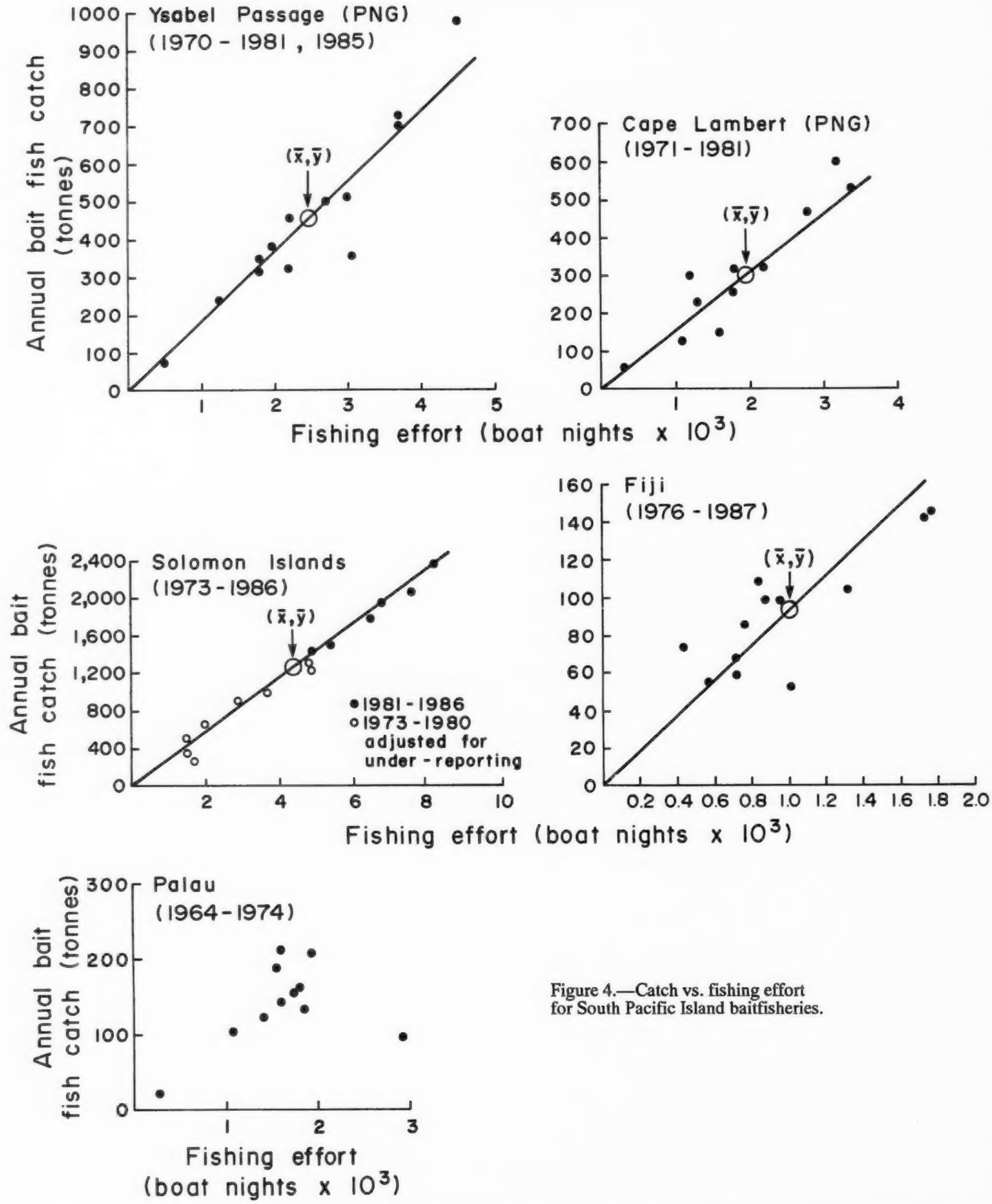

Figure 4.—Catch vs. fishing effort for South Pacific Island baitfisheries.

Philippe[4] estimated the biomass of small pelagic fishes in the lagoons and bays around New Caledonia to range between 0.04 and 1.84 t/km^2 with a weighted mean of 0.46 t/km^2, consisting primarily of anchovies, sprats, and sardines.

[4]Petits, D., and V. de Philippe. 1983. Estimation des stocks de petits pelagiques en Nouvelle-Caledonie, resultats des campagnes d'echointegration. ORSTOM, Noumea, New Caledonia, 85 p.

Estimates of average standing stocks of small pelagics, primarily anchovies and sprats for the Ysabel Passage and Cape Lambert bait grounds in PNG, were 0.59 t/km^2 and 0.29 t/km^2, respectively, with a weighted mean of 0.43 t/km^2 (Dalzell, 1984b). These very limited data suggest that at least around high islands in the South Pacific region, the biomass densities of small pelagic fishes may be relatively similar.

An empirical approach to estimating potential yields (P_y) of pelagic fishes is that described by Marten and Polovina (1982) who showed that there was a relationship between estimated P_y (in t/km^2/year) for tropical pelagic fisheries and primary production (in gC/m^2/year). Dalzell and Pauly[5] updated their compilation with respect to pelagic yields from the Philippines and derived the empircal equation:

$$\log_{10}P_y = 0.0046 \text{ Prime Prod.} - 0.233 \quad (r = 0.661, n = 13, P<0.02).$$

Estimates of primary productivity for the South Pacific region range from 18 to 46 gC/m^2/year (FAO, 1971). Substituting these into the above equation gives potential pelagic yields of 0.71 to 0.95 t/km^2/year. The heavily fished pelagic fisheries of Indonesia and the Philippines comprise between 60 and 70 percent small pelagic species (FAO, 1986). Assuming ecological similarity, this suggests a small pelagic MSY of 0.46 to 0.62 t/km^2/year in the South Pacific region.

A possible alternative approach to estimating yields is the use of sustainable catch rates expressd in tons/n.mi. of 200 m isobath. Polovina et al. (1985) used this technique to make an empirical estimate of the potential yield of *Selar crumenophthalmus* in the Mariana Islands. These authors quoted catch rates of 0.4 to 0.9 tons/n.mi. of 200 m contour from the Hawaiian islands and used these in conjunction with the length of the 200 m contour in the Marianas (490 n.mi.) to suggest harvests of 200 to 440 t/year for these islands.

Comparative data on baitfish catches are given by Gillett and Kearney (1983) summarised from the SSAP. These data refer to catches made at different locations in the South Pacific with a stick-held lift net of 700 m^2. Catch rates ranged from 39 to 291 kg/haul with a mean of 98.2 kg/haul. An analysis of catch, effort, and species composition was made for data collected in Micronesia to assess differences between high islands and atoll lagoons (SPC, 1984). The results suggested that catch per effort at high island sites ($\bar{x}$ = 104 kg/haul) was much higher than at atoll lagoons ($\bar{x}$ = 54 kg/haul). Further, the species composition of bait catches at high island sites was more varied and contained species of stolephorid anchovies.

Other analyses by the SSAP in the same report (SPC, 1984) indicate that there is a greater degree of variability of catch per effort at atoll bait sites than at high island bait sites. It was concluded that atolls in general offer much less potential for commercial baitfishing than high islands, and this may also be the case for small pelagic fish production in total. The productivity potential for small pelagic fishes at atolls is expectedly lower due to relative lack of terrestial input. This has been discussed for coral reef fisheries in general in the Caribbean by Ogden (1982) and the Indo-Pacific by Munro and Williams (1985).

Environmental Effects on Production

Since small pelagic fishes live near the air-water interface, it is likely that climatically induced environmental effects will markedly affect production. Tham (1953) demonstrated that the abundance of catches of stolephorid anchovies (principally *S. heterolobus*) in the Singapore Straits were partially correlated with copepod abundance which, in turn, was correlated with rainfall, phosphate content of the sea water, and standing crop of phytoplankton. A positive correlation has been demonstrated between the recruitment of *Sardinella aurita* in the Mediterranean with sea temperature and rainfall (Ben-Tuvia, 1960). Similarly, Antony Raja (1972) showed that recruitment and catch rates of *Sardinella longiceps* were positively correlated with rainfall off the west coast of India. In Hawaii, Wetherall (1977) demonstrated an inverse relationship between stream outflow into Kaneohe Bay and catch per effort of *Stolephorus purpureus*.

In the South Pacific region, the generally nutrient-poor waters around coral reefs will be enriched by runoff as the result of precipitation. However, rainfall through runoff and stream discharge will also lower salinity and increase turbidity which may have adverse effects on pelagic species. Dalzell (1984a) investigated the effects of rainfall on catches of *Stolephorus* anchovies at two baitfishing locations in northern PNG, Cape Lambert, and Ysabel Passage. The annual rainfall at Cape Lambert ($\bar{x}$ = 2,160 mm/year) is about two-thirds of that at Ysabel Passage ($\bar{x}$ = 3,300 mm/year). Catches of baitfish at Cape Lambert include *S. punctifer*, a stenohaline species. Not surprisingly, the annual abundance of this species as expressed by mean catch per effort declines with increasing rainfall (Fig. 5).

For both *S. devisi* and *S. heterolobus*, Dalzell (1984a) concluded that the catch rates of these species might be modeled with a simple parabolic function of the type $y = a + bx + cx^2$ (Fig. 5). The catch rates at each baitfishing ground were standardized on a per-area basis since the areas fished by the pole-and-line vessels could be accurately defined from the fishing vessel catch data. In both species, the optimum rainfall for maximum catch per effort is about 3,000 mm per year. Note that the additional points for 1985 for Ysabel Passage, which fit rather well, were added without recalculating the curves (Fig. 5).

Muller (1976) has indicated that rainfall enhances recruitment of *S. heterolobus* at Palau. Thus, during years that are drier than average, recruitment and, hence, catch rates of *S. heterolobus* might be expected to decline. However, when rainfall is particularly heavy at Ysabel Passage, catches of *S. heterolobus* and *S. devisi* decline appreciably. Tham (1953) has suggested that such declines with heavy rainfall may be due to the difficulties plankton feeders have in catching their prey in turbid waters or to the effect that a heavy particulate suspension has on the effective functioning of their respiratory systems. The effects of increased turbidity from rainfall on the attractive

[5]Dalzell, P., and D. Pauly. 1987. The fish resource of Southeast Asia with emphasis on the Banda and Arafura Seas. Pap. Pres. at Snellius II Symposium, Jakarta, Nov. 1982. Mimeogr., pagin. var.

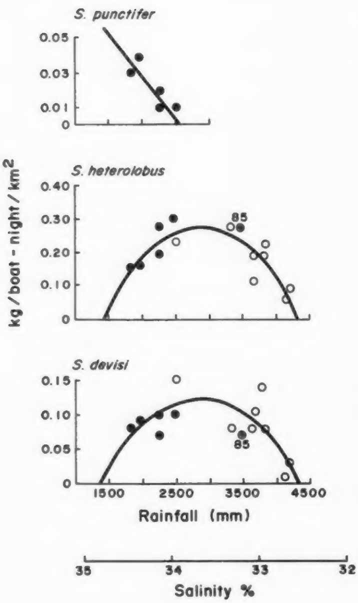

Figure 5.—Mean annual yield of *S. punctifer*, *S. heterolobus*, and *S. devisi* vs. rainfall for two Papua New Guinea baitfisheries. Circles = Ysabel Passage; dots = Cape Lambert. Circles with crosses are the 1985 data points for *S. hetelobus* and *S. devisi* at Ysabel Passage.

power of lights must also be considered, however.

Other investigations of the effect of rainfall on baitfish catches have been made for the Fiji (Ellway and Kearney, 1981) and Kiribati (Ianelli, 1988) baitfisheries. Ellway and Kearney (1981) suggested that rainfall did not markedly affect baitfish catches in Fijian waters. These authors did not, however, investigate the effect of rainfall on individual catch components; rather, they used the catch data for all species. There was also no significant correlation between rainfall and total catch in the Kiribati baitfishery, although the scatter of points of catch rate vs. rainfall presented by Ianelli (1988) suggests an initial increase in catch rates as rainfall increases but with declining catch rates at the highest levels of precipitation. Ianelli (1988) did find, however, a significant positive correlation between catch rate of *Spratelloides delicatulus* and rainfall. Dalzell (1984a) found no correlation between rainfall and catch rates of the congener *Spratelloides gracilis* from the northern PNG baitfisheries.

Catches of small pelagic baitfishes in PNG, New Caledonia, and Fiji are all highly seasonal with peaks in production during the Austral winter when the winds blow predominantly from the southeast. The combined effects of an overlying seasonal pattern with random environmental effects further compound the management problems for these fisheries. Their prime function is a regular and constant supply of live bait for pole-and-line fishing. This means that they can be a serious limiting factor to the tuna fisheries, as has been documented for the PNG pole-and-line fishery by Doulman and Wright (1983).

Despite the extensive nature of the PNG coast, baitfishing was ultimately confined to the two sites, Ysabel Passage and Cape Lambert. Much of the PNG coast is not greatly indented and lacks large harbors. Small ones are common, but the fleet style of operation (i.e., with a mother vessel) could only really utilize areas capable of supporting 10 vessels or more such as Ysabel Passage and Cape Lambert. This was further compounded by sociopolitical problems which confined the PNG pole-and-line fishery to these two sites. The lack of alternative sites during times of low baitfish abundance at Cape Lambert and Ysabel Passage was a serious impediment to the PNG pole-and-line fishery.

The Future of Small Pelagic Fisheries in the South Pacific

The persistence of baitfisheries in the South Pacific is dependent on the pole-and-line tuna fisheries maintaining operations in the region. During the late 1970's and early 1980's, Japanese and U.S. purse-seine fleets began to exploit successfully the skipjack and yellowfin tuna stocks of the South Pacific region. The advent of purse seining has meant that pole-and-line fishing may ultimately be made redundant. Nevertheless, pole-and-line fishing persists in the Solomon Islands, Kiribati, and Fiji. Both Fiji and the Solomon Islands have canneries served by domestic pole-and-line fleets and by purse seine catches. Pole-and-line fishing is politically attractive since it offers employment opportunities to Pacific Islanders.

However, small pelagic fishes are clearly a resource in their own right and are exploited by artisanal fishermen throughout the South Pacific. Accounts in the literature suggest that the commonly exploited species are scads (*Selar* spp., *Decapterus* spp.), herrings (*Herklotsichthys* spp.), mackerels (*Rastrelliger* spp.), half beaks (Hemiramphidae), and flying fishes (Exocoetidae and Hemiramphidae). No accounts were found of artisanal fisheries that regularly catch stolephorid anchovies or *Spratelloides* spp., although these species constitute significant resources in the western South Pacific. Passive gears that catch these fishes in the Southeast Asia such as fish corrals do not appear to be traditionally used in Micronesia and Melanesia, although similar structures known as "parcs" are recorded from French Polynesia (Grand, 1985; Morize, 1985). The principal small pelagic species captured by parcs is *S. crumenophthalmus*.

Anecdotal information and personal communications to the authors from PNG would suggest that prior to inception of the baitfisheries, the anchovy and sprat resources of the coralline shelf of PNG were unexploited. Given the size of this area, Dalzell (1986) has suggested that the potential sustainable yields of stolephorid anchovies from PNG may range from 5–10,000 t/year to 40,000 t/year based on comparisons with similar Southeast Asia fisheries. Whether local fisheries for stolephorid anchovies could prosper in PNG is another matter, however, given the small population (about 3 million people) and lack of markets.

There has been considerable speculation about the effects of the capture of small pelagic baitfish on other reef fisheries. Concern stems from the removal of baitfish species as food for reef-associated piscivorous fishes and the capture of juveniles of reef and lagoon species. Little work has been done to address these questions, although, presently, investigations are being made on this subject in

the Solomon Islands (Nichols[6]). Lewis[7] has suggested that the scale of baitfishing operations are such that the effects of removal of reef and lagoon species may be minimal. Despite the industrial nature of the fishery, the average catch per night by a pole-and-line vessel is small and rarely exceeds 100–150 kg. However, as shown here, long-term fishing may have effects on species composition of bait catches.

Floating fish aggregation devices, or payaos, are commonly used in Indonesia and the Philippines to concentrate small pelagic fishes and tunas (Floyd and Pauly, 1984). Payaos have been used in the South Pacific (Boy and Smith, 1984), but their purpose is to concentrate tunas and large pelagics for trolling or pole-and-line fishing. The exploitation of small pelagic species around payaos appears not to have been considered. This, like the neglected anchovy resources in the region, will probably not change until population levels and economics dictate otherwise. The larger small pelagic species, because of their desirability, will remain exploited at the artisanal level, e.g., by beach seines, handlines, and gill nets, while the smaller clupeoids may continue to be largely unexploited other than for tuna baitfish.

Acknowledgments

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Artificial Habitats for Fisheries Enhancement in the Australian Region

D. A. POLLARD

Introduction

Interest in the construction of artificial reefs in Australia was initially stimulated by the work of Randall (1963) in the Virgin Islands and Carlisle et al. (1964) and later Turner et al. (1969) in California, as well as the early reviews of American and worldwide developments in this field by Stroud and Jenkins (1961), Stroud and Massmann (1966), Unger (1966), and Oren (1968). This interest resulted in the construction, using waste concrete pipes, of Australia's first documented artificial reef in Victoria during the mid-1960's (Anonymous, 1965).

Artificial reef developments in Australia were summarized by Sanders (1974) and Pollard (1976). Although the bibliography on artificial reefs produced by Steimle and Stone (1973) contained only six references to Australian studies, a bibliography listing 137 publications on Australian artificial reefs and fish aggregation devices was published by Pollard and Matthews (1985). Other accounts of Australian developments in this field include a brief review by Pollard (1979) and articles in fishing and conservation magazines by Bowerman (1982), Starling (1983), Deacon (1984), and Hodgson (1986).

This paper outlines in more detail the history and development over about 20 years of projects involving artificial reefs and fish aggregation devices in the Australian region (Fig. 1) and provides information on other artificial fisheries habitat developments in this area.

Multicomponent Reefs

Following the early work on multicomponent reefs carried out in California in the middle to late 1960's (Carlisle et al., 1964; Turner et al., 1969), studies were begun in several Australian states using reefs constructed of similar waste materials.

ABSTRACT—This paper outlines developments over about 20 years in the construction of and ecological research on artificial reefs, fish aggregation devices (FAD's), and other artificial habitats designed to enhance fish populations and fisheries in the Australian region (including New Zealand and Papua New Guinea). Work was initially carried out on multicomponent reefs using a variety of waste materials, as well as some specially constructed concrete and steel structures. Later studies concentrated on single-component reefs, again mainly using waste materials. Although no definitive conclusions were reached on the relative effectiveness of the different materials used, waste motor vehicle tires and derelict ships were generally judged to be the best all-around materials for single-component reef construction in sheltered estuarine and offshore marine environments, respectively, in this region. FAD's comprising polyvinyl chloride pipe spar buoys (or in some areas polyurethane foam floats) attached to railroad car wheel anchors by polyethylene rope and chain, and supporting attractor drapes of synthetic mesh webbing, also proved to be generally successful in this area. Overall conclusions for the Australian region include the predominant use of waste materials in artificial reef construction, which has been primarily aimed at recreational fisheries enhancement; the successful use of FAD's for both recreational and commercial fisheries enhancement; the need for further and better planned research into and monitoring of the effectiveness of both of these enhancement methods; and the need for future research into the effectiveness of unfished "artificial habitat reserves" in enhancing fisheries production from surrounding fished areas.

Victoria

The first documented artificial reef in Australian waters was constructed in October 1965 by the Victorian Department of Fisheries and Wildlife in Port Phillip Bay, near Melbourne. This reef, which was laid in about 20 m of water 8 km off Carrum on the bay's eastern shore, initially comprised around 330 waste concrete pipes, each up to 2.5 m in length and 1.8 m in diameter, weighing in total about 400 metric tons (t). These pipes were barged to the site and sunk on a fine silt bottom over an area of about 4 ha (Anonymous, 1965; Sanders, 1974). Although this reef initially provided good fishing for Australian snapper, *Chrysophrys auratus*, a highly sought recreational species in this area, the concrete pipes gradually sank into the soft substrate and had been scattered over too wide an area to provide a very effective long-term fishing reef. A ferrocement cabin cruiser and a 52 m timber hulk containing about 40 t of concrete ballast were added to this artificial reef in 1967 and 1971, respectively (Sanders, 1974; Beinssen, 1976).

Three multicomponent reefs, each consisting of 100 m^3 of quarry rock, three 1.5 m^3 steel-reinforced open concrete cubes, four 3 m^3 open steel frames, and about 1,000 motor vehicle tires tied in bundles of 8 tires each, were placed on sandy substrates in about 10 m of water in Port Phillip Bay in 1973. These were laid off Mordialloc (near Carrum), Dromana (to the south) and Werribee (to the west), in conjunction with the laying of an ethane pipeline across the bay by Esso-

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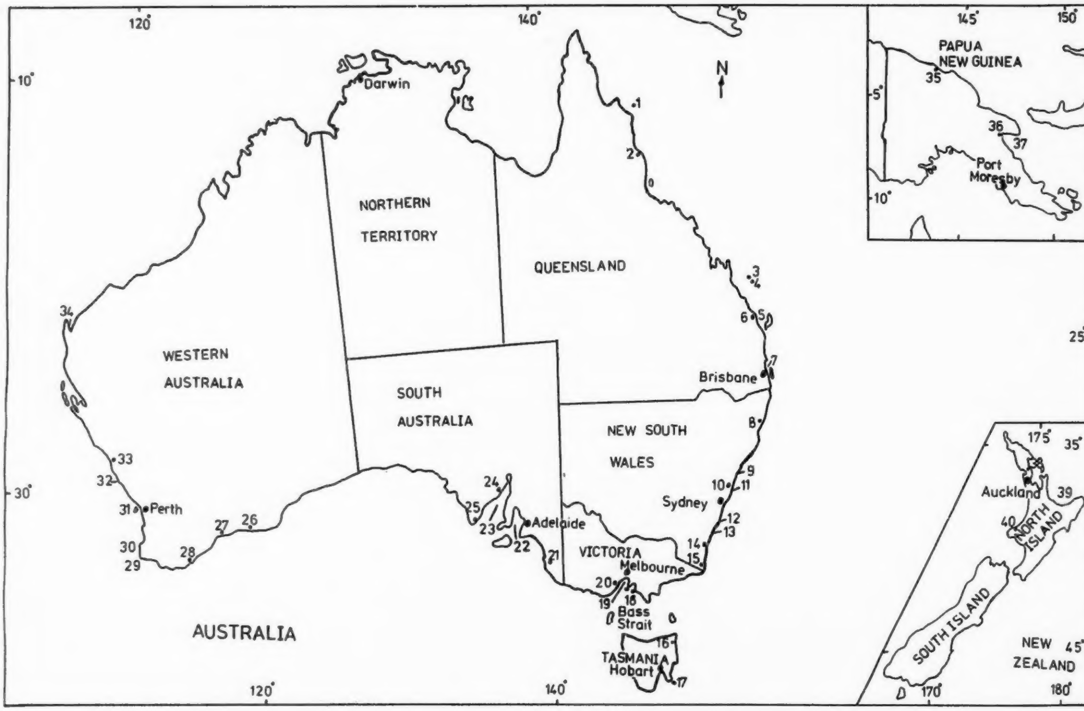

Figure 1.—The main localities in Australia, New Zealand, and Papua New Guinea mentioned in the text. Capital cities (large dots) are named, coastal towns (small dots) are numbered on the landward sides, and other coastal features on the seaward sides of coastlines. Key: 1 = Lizard Island, 2 = Cairns, 3 = Heron Island, 4 = One Tree Island, 5 = Hervey Bay, 6 = Bundaberg, 7 = Moreton Bay, 8 = Coffs Harbour, 9 = Port Stephens, 10 = Newcastle, 11 = Lake Macquarie, 12 = Jervis Bay, 13 = Batemans Bay, 14 = Narooma, 15 = Eden, 16 = St. Helens, 17 = Tasman Island, 18 = Phillip Island, 19 = Port Phillip Bay, 20 = Geelong, 21 = Kingston, 22 = Gulf St. Vincent, 23 = Spencer Gulf, 24 = Whyalla, 25 = Port Lincoln, 26 = Esperance, 27 = Hopetown, 28 = Albany, 29 = Cape Leeuwin, 30 = Cape Naturaliste, 31 = Rottnest Island, 32 = Cliff Head, 33 = Geraldton, 34 = Exmonth Gulf, 35 = Weewak, 36 = Lae, 37 = Huon Gulf, 38 = Leigh, 39 = Bay of Plenty, and 40 = New Plymouth.

BHP Australia[1] (Winstanley, 1972; Sanders, 1974). Diving observations on these reefs showed all of the components except the tires to have been densely settled by mussels, *Mytilus edulis*, within 6 months of their being laid. After 2 years most of the mussels had died off, except those on the steel frames, and the sessile fauna and flora of the remaining reef components were dominated by red algae, sponges, ascidians, and hydroids (Beinssen, 1976).

Like the Carrum reef, these latter reefs supported good populations of Australian snapper (Sparidae), and also ling (Ophidiidae), boarfish (Pentacerotidae), red mullet (Mullidae), beardie and bearded rock cod (Moridae), leatherjacket (Monacanthidae), long-finned sea pike (Dinolestidae) and garfish (Hemirhamphidae), as well as a number of smaller nonangling species. Most of the fish observed on these multicomponent reefs were associated with the tires, which were concluded to "offer by far the most shelter" (Beinssen, 1976).

Locations of these and other Victorian artificial reefs are given by Winstanley (1979), who also commented that, although the concrete pipes, quarry rock, and tires appeared to support the greatest variety and number of fishes sought by anglers, "Development of artificial reefs in Victorian waters has occurred on an ad hoc basis rather than as a planned program, consequently although some observations of established reefs have been made by the Fisheries and Wildlife Division there have not been sufficient resources for systematic monitoring of reef colonisation or for comparison of the effectiveness of different types of materials."

Queensland

Another of the early multicomponent reefs to be constructed in Australian waters, initially consisting of about 50

[1]Mention of trade names of commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

motor vehicle bodies, 1,800 tires, 80 t of concrete rubble and three concrete "fish houses," was laid in 18 m of water off Woody Island in Hervey Bay, southern Queensland, in 1968 by a consortium of local skindiving, angling, boating, and conservation interests. By mid-1973 this reef had been expanded to include some 220 motor vehicle bodies, around 10,000 tires, several derelict wooden and steel barges (between about 25 and 55 m in length), around 400 t of concrete rubble, and 12 concrete "fish houses" (Davie, 1971; Anonymous, 1971, 1973; Pollard, 1976). By 1974 this reef covered an area of some 32 h, and has since been expanded.

After about 5 years, the oldest parts of the Hervey Bay reef were covered with thick growths of soft corals, gorgonians, and sponges, and supported over 70 species of fishes, including many of recreational fishing importance, compared with only 15 fish species observed during preconstruction underwater surveys in this area (Thompson, 1973). Soon after its establishment, a ban on spearfishing on this reef was imposed, though angling pressure on it has apparently remained high. A tentative estimate of this angling pressure for 1973 was ~200 angler hours per week, resulting in an average catch rate of ~0.5 fish per angler hour. The main target species were Australian snapper, tusk fish (Labridae), and sweetlip (Lethrinidae) (Sanders, 1974).

A reef constructed of similar materials, but including a quantity of large (1.5 × 3.5 m and 1.5 × 6.7 m) metal pipes and a number of derelict steel vessels ranging from 20 to 45 m in length, was started in Moreton Bay (just to the north of Brisbane in southern Queensland) in 1968, and added to over subsequent years. At the most recent report this reef comprised some 11 vessels, one tram car, 60 car bodies, 500 tires, 36 steel pontoons, and 7 t of concrete pipes (Underwater Research Group of Queensland, 1985). This reef is located off Cowan Cowan, on the northwestern shore of Moreton Island, on a sandy bottom in around 20 m of water, and was initiated by the Underwater Research Group of Queensland with the assistance (as a training exercise) of a local Citizens Military Forces Water Transport Squadron (Anonymous, 1971; Davie, 1971). A similar assemblage of fish species to that found on the Hervey Bay reef was observed during diving surveys carried out by the Queensland Littoral Society soon after its construction, with approximately 80 species having been observed there by the end of 1970. Conspicuous amonst the fish fauna at the Moreton Bay reef, which is also closed to spearfishing, were very large specimens of estuary cod, *Epinephelus malabaricus*, and giant Queensland grouper, *E. lanceolatus*, observed in 1975 around several of the sunken vessels (personal observation).

Following an advertisement by the Queensland Government Tourist Bureau encouraging visiting anglers to fish the Hervey Bay Reef, the umbrella group (the Maryborough and Hervey Bay Artificial Reef Committee, which included both local angling and skindiving groups) which had initiated the construction of this reef and instigated its closure to spearfishing, also advocated its closure (at least temporarily) to angling. The rationale given was the importance of this reef as a "seeding area" for surrounding waters, and thus its value in "building up the fish population in Hervey Bay" (McDonald, 1973a). Similar comments were subsequently made in relation to the Moreton Bay reef, such that, although "the reef was built to see if fish could be brought back into Moreton Bay... the new fish population faced the danger of being fished out before being firmly established" (McDonald, 1973b).

Based on observations of these two Queensland multicomponent reefs, the Queensland Littoral Society concluded that: "Outstanding success had been achieved with rubber tyres bound into lots of five as reef material. Motor car bodies are also successful, despite their short life" (of about 5 years) (Anonymous, 1971).

A further multicomponent reef, comprising a number of derelict launches, many bundles of tires, and a variety of other waste materials, was also constructed in southern Queensland (in Southport Broadwater, just to the south of Moreton Bay) by the Gold Coast Underwater Club in 1972 (Sanders, 1974; Smith, 1976). This reef was also closed to spearfishing, though it apparently provided good angling, and a number of large estuary cod (Serranidae) were observed on it in 1975 (personal observation). Another small multicomponent reef was constructed in Moreton Bay (off Woodgate) using waste bricks, concrete pipes, and old machinery in 1978 (Starling, 1983), but no information on this reef's subsequent effectiveness is available.

South Australia

An unknown number of motor vehicle bodies was placed off Port Broughton in upper Spencer Gulf, South Australia (S.A.), by local angling interests in the late 1960's. However these, in contrast to those placed in Hervey and Moreton Bays in Queensland, were still relatively intact after around 20 years' immersion[2]. No information is available on their effectiveness.

Concrete Module Reefs

The idea of using reefs constructed of small concrete modules for experimental ecological studies in Australia originated from the early work along these lines carried out by Randall (1963) in the Virgin Islands.

Queensland

Experimental work on fish recruitment patterns using reefs constructed of small concrete modules was carried out during 1971 in 3-5 m of water in the lagoon at One Tree Island (at the southern end of the Great Barrier Reef) by Russell et al. (1974). These authors compared two series each of eight reefs (one laid in summer and the other in winter) comprising solid and hollow concrete blocks of dimensions 160 × 60 × 60 cm. These reefs attracted large populations of small coral reef fishes, though no firm results emerged in relation to differences due to habitat structure (Talbot et al., 1978). Comparisons with similar small concrete module reefs in Florida (Bohnsack and Talbot, 1980) showed that reef fishes rapidly colonized such small experimental reefs in both areas, where they also supported similar total numbers of species and families, numbers of species per residence category, and mean numbers of individuals per reef, despite the fact that the Australian locality had approximately twice the

[2]K. Branden, S. A. Department of Fisheries, Adelaide. Personal commun.

species pool available for colonization. Similar concrete module reefs have been used more recently (during the early 1980's) to study predation of juvenile reef fish at Lizard Island on the northern part of the Great Barrier Reef[3].

Western Australia

Concrete shelters were used by the C.S.I.R.O. Division of Fisheries and Oceanography in studies of juvenile western rock lobsters, *Panulirus cygnus*, off Cliff Head, southwestern Western Australia (W.A.), in 1971-72 (Anonymous, 1970a). These shelters were placed in 4.5 m of water about 2 km offshore, but tagged rock lobsters placed on them had reportedly left the reefs by the time they were resurveyed about 1 month later (Chittleborough, 1973).

New South Wales

Although no studies have been carried out to date using small-scale concrete module reefs in New South Wales (N.S.W.) waters, small reefs consisting of pyramidal bundles of earthenware pipes have been used in experimental studies on fish recruitment in Sydney Harbour (Lincoln-Smith, 1978). These small experimental reefs supported larger numbers of "substratum-associated" fishes, in terms of both species present and their abundances, when compared to the flat areas of sea floor upon which the reefs were built. Non-substratum associated fishes were, however, more common in terms of both numbers of species and individuals present over such areas of flat bottom and also around nearby areas of natural reef.

The ecology of fish communities occupying both a natural rocky reef and a large-scale concrete module port revetment wall in Botany Bay, in the southern suburbs of Sydney, were studied by Burchmore et al. (1985) over a two year period between 1977 and 1979. Fish species present were censused bimonthly using a quantitative diver transect method at both sites, and spatial and temporal differences in fish community structure were analyzed. One hundred and two fish species from 50 families were observed, 93 at the natural reef site and 50 at the artificial reef site, with 49 species being common to both. Twenty-five of these species were of some recreational and/or commercial fishing importance, and although the natural reef site supported a larger number of fish species and a higher total abundance of fish, the artificial reef site attracted slightly larger abundances of fishes of economic importance (Burchmore et al., 1985). This result contrasted with the findings of Randall (1963), who found an order of magnitude higher biomass of fish on a concrete block artificial reef compared with a natural coral reef in the Virgin Islands.

Apart from the these small experimental concrete module reefs, and the small-scale use of concrete "fish houses' in some of the multicomponent reefs, no larger-scale specially built concrete "production" reefs have yet been constructed in Australia. Most of the effort has been concentrated on the use of waste materials for reef construction. Although the different multicomponent reefs described consisted of a variety of miscellaneous waste materials, the main single-component reefs have been constructed using waste motor vehicle tires and derelict ships.

Tire Reefs

The idea of using waste motor vehicle tires for artificial reef construction (first adopted in New South Wales in the late 1960's and in South Australia in the early 1970's), originated from an early booklet on this subject by Edmund (1967).

New South Wales

Australia's first documented tire reef was constructed in 1966 by the Newcastle Underwater Research Group using 250 car tires which were sunk, together with a single motor vehicle body, in 8 m of water in Lake Macquarie, a large estuarine coastal lagoon just south of Newcastle in central N.S.W. (Wharton, 1970). However, the car body and the wire used to bind the tires soon rusted away and the tyres were dispersed on the estuary floor. N.S.W. State Fisheries[4] became concerned about the possible future indiscriminate aquatic disposal of waste materials, sought to develop more soundly constructed artificial reefs, and in 1969 chose Lake Macquarie for the construction of several experimental tire reefs.

Four small reefs, each consisting of about 660 car tires, were laid in the northern half of this coastal lagoon in about 10 m of water between October 1969 and July 1970 (Anonymous, 1970b, c; Malcolm and Matthews, 1970). Three such reefs were laid on muddy sand bottoms in areas where the water proved to be too turbid for regular underwater observation, but the fourth, located on a clean sandy bottom near the lake's entrance channel to the sea, proved very suitable for diver observations of its fish fauna. This reef consisted of 22 unanchored triangular-profiled bundles, each of 30 tires (tied into cylinders of 10 and then into pyramidal bundles of 30 using polypropylene rope), placed in an open circle or horseshoe-shaped arrangement on the lake floor (Fig. 2). Fish censuses and observations of this reef's sessile flora and invertebrate fauna were subsequently carried out opportunistically over the following 8 years, with night censuses also being carried out over the last 3 years of the study (Fig. 3).

Studies on this reef included observations on the temporal development and succession of the invertebrate fauna and flora, long-term and seasonal changes in the composition and abundance of the fish community, diurnal changes in fish activity patterns and behaviour, and the residence status and location on and around the reef of various life history stages of the main fish species present.

Overall, 78 species of fishes belonging to 44 families and comprising a total of around 12,500 individuals were observed on the reef during 25 censuses carried out over the study period (Fig. 4). Following an initial 3 year period of primary colonization and "community development", during which a total of 31 fish species was observed at the reef (day censuses only), an additional 25 species were observed during the second, and another 22 species during the third 3-year period of the study (day and night censuses). During the latter two 3-year periods, a total of 72 species was observed by day (averaging 27

[3]G. Anderson, Macquarie University, Sydney. Personal commun.

[4]Now the Division of Fisheries, N.S.W. Agriculture and Fisheries.

species per census) and 50 by night (averaging 24 species per census). The main peaks in species numbers occurred in summer-autumn and the main troughs in winter-spring during the latter 6-year period.

The ten most "common" species on this reef (based on a multiple of their estimated total abundance and their frequency of occurrence) included three scorpidids, a monacanthid, an apogonid, a carangid, two plotosids, a dinolestid, and an enoplosid. The most heavily represented family was the Serranidae, followed by the Monacanthidae, Pomacentridae, Labridae, Carangidae, Scorpaenidae, Tetraodontidae, and Chaetodontidae. Although most of the species observed were of Peronian (south-central eastern Australian warm temperate, here including widespread) zoogeographic affinities, 20 species (mainly present during summer-autumn) were found to be of Solanderian (northeastern Australian tropical) affinities, and no Maugean (southeastern Australian cool temperate) species were observed. Among the 25 species present which were judged to be of economic value, the ten most abundant belonged to the families Carangidae (2 spp.), Dinolestidae (1 sp.), Monacanthidae (1 sp.), Kyphosidae (1 sp.), Sparidae (3 spp.), Gerreidae (1 sp.), and Cheilodactylidae (1 sp.). The succession of dominant sedentary invertebrate fauna on the reef comprised barnacles, mussels, and then sponges, in that order (Fig. 5). The tires and their attachment ropes were found to be in generally sound condition after 9 years' immersion (Pollard et al., 1987).

Similar small tire reefs were subsequently laid in a number of other locations in N.S.W. during the mid 1970's, including Batemans Bay (on the mid south coast), Port Stephens (on the mid north coast), and Port Hacking (just south of Sydney). Only the latter reef was monitored, and in this case, although the tire bundles used were constructed with a higher profile (each comprising 10 cylinders of 10 tires, attached with plastic packaging strap and polythene buckles), it was subsequently found that this site was too deep (about 25 m) and too far upstream in the estuary to provide effective habitat for a variety of estuarine fish (Fig. 6). Only 25 species were observed over the next 2 years[5].

Figure 2.—Tire reef units being laid in Lake Macquarie, 1970.

Figure 3.—Diver recording biological data on Lake Macquarie tire reef, 1975.

South Australia

Another study using tire reefs was carried out in Gulf St. Vincent near Adelaide by the S.A. Department of Fisheries in the early 1970's (Sanders, 1974). The first of these reefs was constructed on a sandy bottom in around 10 m of water about 4 km off Henley Beach (near Grange) in 1970, and consisted of about 15,000 tires which had been slit and tied with plastic packaging tape into cylindrical bundles of around 8-10 tires. Unfortunately, this reef, in which no anchoring was employed, was largely dispersed and buried during a one-in-thirty-year storm less

[5]D. Pollard and J. Matthews, N.S.W. Fisheries Research Institute, Cronulla. Unpubl. data.

Figure 4.—School of blackfish, *Girella tricuspidata*, around Lake Macquarie tire reef, 1975.

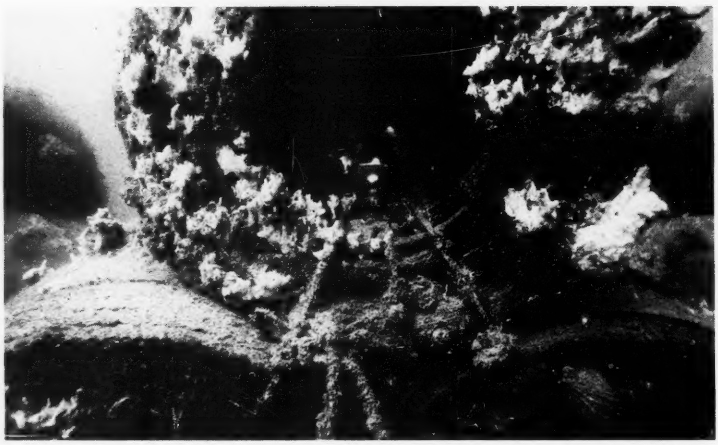

Figure 5.—Sponges and other encrusting organisms on Lake Macquarie tire reef, 1975.

than a year after being laid. A second reef comprising some 25,000 tires was subsequently laid, also near Adelaide, on a sandy substrate close to a natural calcareous reef in about 18 m of water about 5 km offshore from Glenelg in 1973. This reef was also partially dispersed over subsequent years by winter storms (Olsen et al., 1976).

In general, the dominant attached fauna and flora on the tires of both reefs comprised oysters and encrusting serpulid polychaete tubeworms, together with some ascidians and a variety of algae (the latter forming about 60 percent cover on the remaining tires of the Grange reef after about 3 years). Although 6 fish species were observed on the Grange reef about 6 months after it was laid and before it was dispersed by storm damage, only 3 species were observed on its remains during the following 3 years. About 17 fish species (including 5 or 6 of some economic importance), however, were observed on the Glenelg reef about 1 year after its construction, and 27 species after 4 years (Branden, 1976). This greater diversity of fish may have been due to this reef's location close to an area of natural reef. The latter artificial reef was also reported to be popular among sport fishermen, some of whom claimed to have taken good catches of King George whiting (Sillaginidae) and Australian snapper from it (Olsen et al., 1976).

Olsen et al. (1976) concluded from the above studies that: "Overall, the results from both reefs suggest that the provision of shelter by the tires is more important than the development of an attached community of organisms on them (which may be a source of food) in attracting fish to the artificial structure."

Following the placement of the first tire reef off Grange in 1970, several smaller tire reefs were laid by local fishing groups under the supervision of the S.A. Department of Fisheries at other South Australian locations near Whyalla (5,000 tires in 1971), Port Lincoln (2,000 tires in 1972), Kingston (700 tires in 1972), Port Vincent (1,400 tires, date unknown), and Robe (number of tires and date unknown) (Sanders, 1974; Olsen et al., 1976), though no information appears to be available on the subsequent effectiveness of these reefs. Another tire reef was laid in about 15 m of water near Whyalla in 1983, which comprised around 50 t of large earth-moving machinery tires (each weighing over 200 kg) together with about 10 t of waste concrete pipes (Daniels, 1984), though again no reports are available as to this reef's effectiveness.

The most recent tire reef program in South Australia, and so far Australia's largest in terms of both the numbers of tires laid and its cost, has been that carried out by the S.A. Department of Fisheries between 1984 and 1986. During this period around 7,000 "tetrahedron module units" were constructed, each comprising 28 ventilated tires secured by polyester tape and stainless steel crimp seals, with the nine basal tires being weighted with concrete. These tire reef units, each weighing around 250 kg, were placed at 7 sites of low fish abundance at depths of at least 15 m (to avoid storm surge damage) in both Spencer Gulf and Gulf St. Vincent. They were constructed

using unemployment relief labor at a total estimated cost of $A1.2 million (Branden and Reimers, 1987).

By late 1987 almost 70 species of fishes had been recorded on these reefs, about half of which were spcies of some recreational and/or commercial fisheries value, including such highly sought angling species as Australian snapper and King George whiting. So far about 60 species of algae have been identified on the reefs, and algal succession is also being studied using removable tire-rubber panels placed on them at 2-month intervals[2].

Other Australian States

Apart from the use of tires in the multicomponent reefs described above in both Queensland and Victoria, a small reef comprising 80 tires was also constructed on a flat sandy bottom off Rottnest Island near Pearth in southwestern W.A. by the Underwater Explorers Club of W.A. in 1971, with the aim of providing home sites for rock lobsters (Sanders, 1974). Another reef of 2,000 tires was also placed in about 10 m of water off Portarlington in Port Phillip Bay near Geelong, Victoria, by the Barwongrove Skindivers Club in 1973 (Beinssen, 1976). No further information is available on the effectiveness of either of the latter two reefs, or of another small tire reef laid near Rous Light in Moreton Bay, Queensland, by a local trailer boat club in 1975 (Starling, 1983).

New Zealand

Russell (1971, 1975) constructed a small experimental tire reef near Leigh off the northeastern coast of New Zealand during the early 1970's and found it to support a very high fish biomass, equivalent to 10-14 times the standing stock of nearby natural rocky reefs. The bulk of this biomass was accounted for by a species of red mullet which "aggregated in large numbers around the reef" . . . but "fed mainly by grubbing about on the surrounding sand" (Russell, 1976). From this study, and the observations of other workers in California and Hawaii, Russell noted that such "peripheral-living" sand-dwelling species were often important components of artificial reef fish populations, and in consequence suggested that large numbers of small reefs (which would maximize the available ecotone areas) may prove to be more effective than smaller numbers of larger ones (Russell, 1976).

Figure 6.—Tire units being barged to Port Hacking artificial reef site, 1977.

Ship Reefs

Although sunken boats and barges had been used previously in several of the multicomponent reefs described above (e.g., in Port Phillip Bay in Victoria, and Moreton and Hervey Bays and Southport Broadwater in southern Queensland) during the late 1960's and early 1970's, the first large offshore reef consisting entirely of derelict ships was commenced in N.S.W. waters off Sydney in the mid 1970's (Pollard, 1976).

New South Wales

The first of the vessels, an 88 m Sydney Harbour ferry, was sunk on a flat sandy bottom in about 45 m of water about 3 km offshore from Narrabeen in the northern suburbs of Sydney in May 1976 (Anonymous, 1976). A 67 m linseed oil tanker was added to the reef site in December of that year, and about another 10 vessels ranging from 20 to 75 m in length were added between that time and the early 1980's (Fig. 7). By 1979, divers from N.S.W. State Fisheries had noted 25 species of fish on this reef, ranging from small baitfish such as yellowtail, *Trachurus novaezelandiae*, to 15 kg yellowtail kingfish, *Seriola lalandi*, and similar-sized mulloway, *Argyrosomus hololepidotus*. Recreational and commercial fishermen using lines and traps, respectively, reported good catches of the latter two species, plus Australian snapper, teraglin (Sciaenidae), and several other species, from this ship reef during the late 1970's (N.S.W. State Fisheries, 1979) (Fig. 8).

In addition to diving surveys of some of the ships comprising this reef, which lies in 45-55 m of water, and hence near the limit of convenience for scuba diving surveys of sufficient duration, the reef has also been surveyed using the small manned research submarine *Platypus* (Anonymous, 1982a), and also an unmanned robot submersible, the "TREC" (Tethered Remote Camera), equipped with color video cameras and a remotely controlled arm and claw (Anonymous, 1984).

Other Australian States

Apart from the various artificial reefs containing derelict vessels mentioned above and the many accidental shipwrecks scattered around the Australian coastline which have proved to be excellent fishing spots, a number of other vessels have been

Figure 7.—Sinking of the linseed oil tanker *Meggol* at the Narrabeen artificial reef site, 1976.

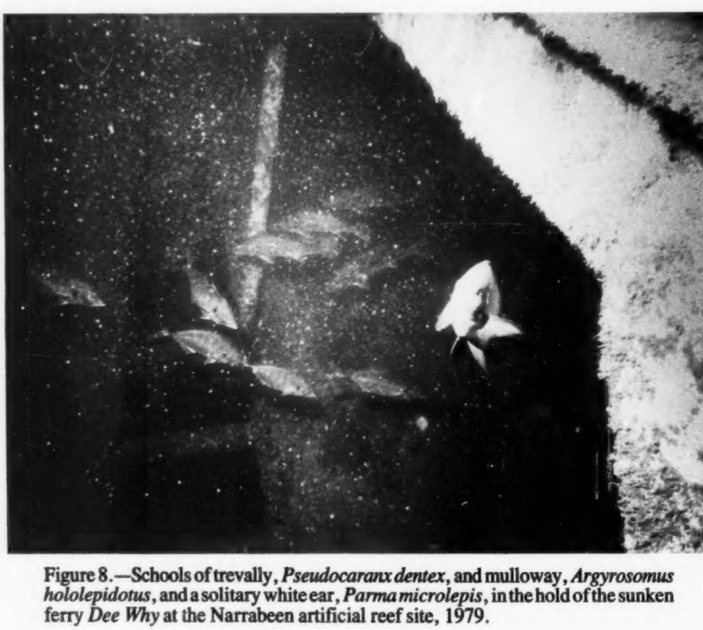

Figure 8.—Schools of trevally, *Pseudocaranx dentex*, and mulloway, *Argyrosomus hololepidotus*, and a solitary white ear, *Parma microlepis*, in the hold of the sunken ferry *Dee Why* at the Narrabeen artificial reef site, 1979.

sunk for this specific purpose in Australian waters. These include a 74 m bucket dredge sunk in ocean waters at 20 m depth off Phillip Island, Victoria, in 1976 (Winstanley, 1979); a 39 m Vietnamese refugee boat and a 35 m pontoon sunk in Darwin Harbour, Northern Territory, in 1982 (Starling, 1983); and two 43 m hopper barges sunk in about 20 m of water off Glenelg and Ardrossan in Gulf St. Vincent, South Australia, in 1984 (Branden, 1984). Little information is available on the success of these latter ship reefs, though at Glenelg, boarfish, leatherjackets, trevally (Carangidae), and a number of other smaller species of fishes were observed by divers about a month after sinking (Branden, 1984).

Fish Aggregation Devices

Initial experiments with surface and midwater fish aggregation devices (FAD's) in Australian waters were inspired by the early observational studies on fish attrac-

tion to floating structures by Gooding (1965) and Gooding and Magnuson (1967) in Hawaii, and subsequent experimental work on FAD's by Wickham et al. (1973) and Wickham and Russell (1974) in the Gulf of Mexico off Florida.

New South Wales

The first known experiments with FAD's in Australia were carried out by J. Matthews of N.S.W. State Fisheries and the author in 1978. Attempts were made at this time to place a tent-shaped attractor consisting of a polyvinyl chloride (PVC) pipe frame covered with white vinyl cloth beneath the buoy (a foam-filled Boeing 707 aircraft tire) which had been attached by chain to the hull of a sunken ferry to mark the position of the Narrabeen Ship Reef (see above) for the benefit of anglers and divers. Although this FAD (similar to that illustrated in Matthews, 1973) was of generally similar construction to those used by Wickham et al. (1973) in the Gulf of Mexico, it was rapidly broken up by the strong current which often prevails in this area.

As the marker buoy was also lost soon afterwards (again probably due to the strain on it from the current), a replacement spar buoy constructed of 20 cm diameter PVC pipe was attached to the ferry using wire cable in 1979. Another attractor, constructed of a stronger PVC pipe frame within which was stretched a rectangle of black plastic mesh, was attached in midwater beneath this buoy. This FAD was observed to attract schools of small scads (Carangidae) and other baitfish, as well as numbers of large yellowtail kingfish, before both it and the buoy to which it was attached were lost some months later, in this case apparently due to human interference.

Figure 9.—Diver sampling baitfish schooling around midwater FAD attractor drape, 1980.

A further experimental FAD was constructed in 1980, comprising a 4 × 15 m rectangle of black plastic mesh suspended at 4 m depth below a buoy constructed of 2 × 200 liter foam-filled oil drums. This FAD was placed about 30 km offshore from Sydney in about 180 m of water (Anonymous, 1980) (Fig. 9). Three similar FAD's were subsequently placed off the southern N.S.W. coastline in the vicinity of Jervis Bay (1) and Eden (2) in 1981, with the aim of attracting commercial quantities of southern bluefin tuna (Scombridae). These FAD's consisted of 13 × 18 m polyethylene netting "flags" (or a 9 m long netting cone in the case of the Jervis Bay site) attached 10 m below similar buoys (i.e., 2 × 200 liter foam-filled oil drums attached end to end, and in this case surrounded by a collar of foam-filled PVC pipes to provide extra flotation). These buoys supported a conical battery compartment, a radar reflector, and a flashing amber light triggered by a photosensitive switch, and were attached to 500 kg concrete anchor blocks by 300 m of PVC-covered 6 mm galvanized wire and a short ground chain (Fig. 10). Unfortunately, all of these FAD's had disappeared within several months of their placement and before their fish attraction potential could be adequately assessed and monitored (Matthews and Butcher, 1983). Although no southern bluefin tuna were reported, anecdotal evidence from both recreational and commercial fishermen suggested that they were successful in attracting a number of other pelagic fish species, including scads and yellowtail kingfish.

Further experiments were carried out

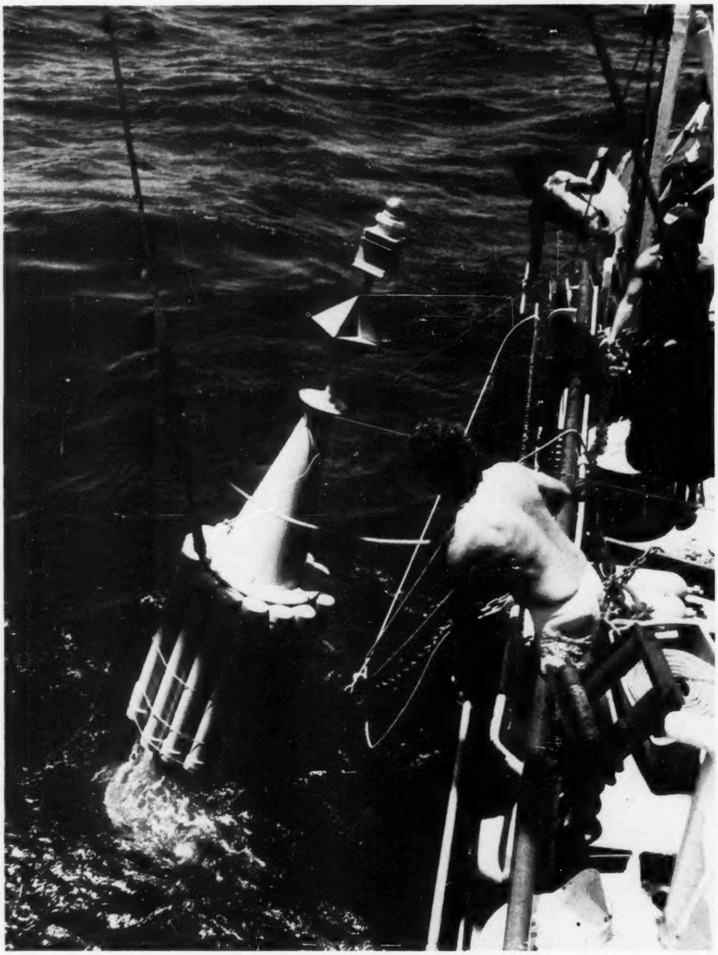

Figure 10.—FAD being deployed from FRV *Kapala*, 1979.

by J. Matthews in 1982 using buoys constructed of 3 × 200 liter foam-filled oil drums mounted side by side in a hardwood frame with a counterweight beneath. These buoys had the same radar reflection and lighting arrangement as the above, were attached to a 1,050 kg concrete anchor, and supported an attractor drape of plastic strapping woven into netting. These FAD's were placed off Sydney (3), Port Stephens (1), and Narooma (1), but again most of them were lost within about 3 months of placement. However, before their loss (which was again attributed to the strong current, heavy swell, and possibly also shipping in this offshore area), diving and trolling surveys on some of these FAD's showed good populations of small baitfish (mainly scads) and also such popular angling species as yellowtail kingfish and dolphin fish (Coryphaenidae). Amateur anglers also reported catches of these two species, as well as albacore, yellowfin and skipjack tunas (Scombridae), and sharks, and also sightings of marlin (Istiophoridae) around these FAD's before they were lost.

Developments in this FAD program since 1983 have involved a return to the use of current and swell-resistant spar buoys, since the 2 and 3 × 200 liter oil drum designs, which had reputedly proven successful overseas, had consistently failed in the strong current and high shipping activity areas where they had been deployed off the N.S.W. coastline. These spar buoys are constructed from 6 m lengths of 315 mm diameter heavy duty PVC pipe filled with polyurethane foam for floatation. Concrete (~70 kg) is poured into the bottom ends of the pipes for ballast, aluminium foil placed in the top ends for radar reflection, and end caps attached using PVC glue and 18 mm diameter steel center rods threaded at the top end and bent to form a ring at the bottom. The mooring assembly consists of a ~450 kg railroad car wheel as the anchor, 10 m of ground chain, ~1.2 times the water depth of 28 mm polyethylene rope, and 10 m of top chain attached to the buoy via a swivel. All connections are made using hammerlocks and hard eyes. The attractor drape, which comprises a 10 × 2 m section of 45 mm welded cross-strip plastic webbing, is attached to a light chain and thence to the mooring system at the selected depth[6].

Nine of these FAD's, several of which lasted for more than 6 months, were deployed off Sydney during 1983-84, and fish species attracted to them included a variety of small baitfish, yellowtail kingfish, rainbow runner (Carangidae), dolphin fish, yellowfin and skipjack tunas, and sharks (Matthews and Butcher, 1986) (Fig. 11).

The most recent FAD to be located in N.S.W. waters by the Fisheries Research Institute was placed in 75 m depth off Coffs Harbour, in the north of the state, during 1986. Although this FAD, which was of similar design to the above, was lost within 6 months of its placement, it was observed to attract large numbers of a variety of fish species, including yellowtail kingfish, rainbow runner and amberjack (Carangidae), cobia (Rachycentridae), dolphin fish, various species of sharks, leatherjackets, and small baitfishes. One notable catch by two members of a local sportfishing club at this

[6]J. Matthews, N.S.W. Fisheries Research Institute, Cronulla. Personal commun.

FAD "resulted in 158 dolphin fish being tagged and released in one session" (Anonymous, 1986).

Western Australia

A number of FAD's were placed at four locations off Esperance and Hopetown in southwestern W.A. in 1980-81 by the W.A. Department of Fisheries. The buoys for these comprised 3 × 200 liter foam-filled oil drums in steel frames supporting lights and radar reflectors, and were attached to 1,500 kg concrete anchors in 120-200 m depths using polypropylene rope and chain. Attractor drapes, which were hung from the buoys, comprised 15 m lengths of rope attached by wooden crossbeams and supporting rope-fiber bundles. Problems were experienced with buoys breaking up and dragging their anchors, but commercial fishermen made good catches of southern bluefin tuna around them by pole and line live-bait fishing, as well as catching some bigeye and skipjack tunas and sharks (Anonymous, 1981a, b). The estimated minimum contribution of these FAD's to the total tuna catch of this area in 1980-81 was 34 percent (Starling, 1983).

Although all of these FAD's eventually broke away, one lasted for 18 months. The buoys used were subsequently changed to fiberglass-coated high-density polyurethane blocks and the anchors to two railroad car wheels attached in tandem, and nine of these newer-design FAD's were placed off the south coast between Albany and Esperance during 1983. A further 10 were deployed off the south coast in 1984, in addition to one at Cape Leeuwin, one at Cape Naturaliste, and three off Exmouth Gulf. Unfortunately, "feedback from professional and amateur fishermen on the success of this programme has been disappointing" (Anonymous, 1987).

In addition to the above FAD's, which were placed primarily for the benefit of commercial tuna fishermen by the W.A. Department of Fisheries, amateur fishing groups in that state have also placed a number of FAD's off Rottnest Island, near Perth, since the early 1980's. Good catches of dolphin fish and tunas have since been made around these structures (Starling, 1983; Roennfeldt, 1984).

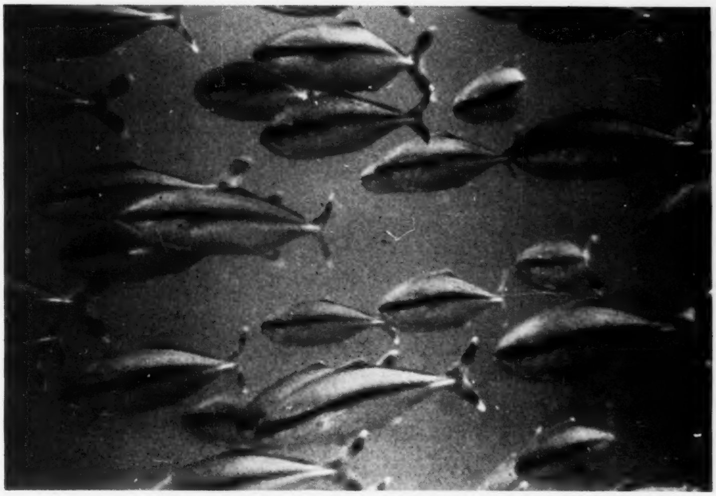

Figure 11.—Yellowtail kingfish, *Seriola lalandi*, schooling around a FAD off Sydney, 1983.

Queensland

Although a FAD was reportedly placed off Moreton Island in southern Queensland by amateur angling interests in 1981 (Orr, 1981; Bowerman, 1982), no information is available as to its success. However, during 1982 three further FAD's were placed off Bundaberg, further to the north, and these reportedly provided good fishing for yellowfin tuna and Spanish and school mackerels (Scombridae), black marlin and sailfish (Istiophoridae), and cobia (Rachycentridae) (Starling, 1983).

Two more FAD's were placed over a shallow seamount about 80 n.mi. off Cairns in the north of this state during 1982 to attract tuna for commercial handline and pole fishing in that area. The buoys used were of fiberglass-covered polystyrene supporting masts with radar reflectors and flashing lights, and under which were suspended drapes comprising 2 m lengths of plastic binding tape inserted into the lay of 20 m of "terryprop" rope (Anonymous, 1982b). No reports have been received on the effectiveness of these FAD's, or on a number of others placed in southern Queensland waters by local angling interests since that time (Steptoe, 1984).

Tasmania

A FAD of similar design to those used off Cairns was placed in ~150 m depth off Tasman Island in southeastern Tasmania in 1982 to attract southern bluefin and skipjack tunas (Anonymous, 1982c), although no report as to its success has yet been published. A further FAD was placed in 110 m depth off St. Helens in northeastern Tasmania in 1983, and although no details of its construction are available, good catches of albacore and skipjack tuna and sightings of southern bluefin tuna and marlin were subsequently made in the area (Wilson, 1983).

Other Australian States

A single experimental FAD, consisting of an inverted cone of netting about 5 m deep and suspended in midwater, was placed by the S.A. Department of Fisheries in 23 m depth off Onkaparinga Head in Gulf St. Vincent, just south of Adelaide, in 1982 (Gartside and Branden, 1983), but no reports of its effectiveness have appeared to date.

Although no FAD's have yet been constructed in Victorian waters, the Victorian Department of Fisheries has been monitoring fish populations around oil

production platforms in Bass Strait (which provide excellent nonpurpose built fish attractors) in relation to the possible future development of FAD's, and also the possible eventual use of these platforms as artificial reefs, in this area.

New Zealand

The first FAD to be placed in New Zealand (N.Z.) waters was located off Mayor Island, in the Bay of Plenty to the south east of Auckland, in 1982, and consisted of "a lattice of aluminium tubes with a 20 metre length of net hung beneath it, the net being laced with streamers of blue plastic parcel strapping." Although this FAD was constructed by a commercial fishing company with the aim of aggregating small schools of skipjack tuna present in this area for purse-seining purposes (Anonymous, 1982d), no information as to its success has subsequently been reported. Other FAD's have since been deployed in N.Z. waters by sport-fishing clubs, such as that located in the North Taranaki Bight near New Plymouth (Baty, 1988), though again no information on their success is available.

Papua New Guinea

The use of small-scale fish aggregation devices by artisanal fishermen in Papua New Guinea (P.N.G.) was reported on by Frusher (1986). In this study by the Fisheries Research and Surveys Branch of the P.N.G. Department of Primary Industry, two FAD's were deployed in 160 and 390 m of water along the northern coastline near Wewak in 1984. These consisted of two or three 200 liter foam-filled oil drums welded in an angle-iron frame and anchored by rope and chain to discarded engine blocks. No information was given on attractor drape materials or design. Although the shallower of the two FAD's "proved unsuccessful both in the amount of fish it aggregated and the consistency with which they were aggregated," the deeper (390 m) FAD "provided consistent troll catches averaging 12 kg/hr/vessel, with several catches exceeding 40 kg/hr/vessel." This deep-water FAD tripled the annual harvest of tunas by artisanal fishermen in the Wewak area. However, the fish caught around the FAD were significantly smaller than those normally caught in the artisanal fishery. Frusher (1986) also commented that, "while FAD's appear as a bonus to P.N.G. artisanal fishermen, their harvest of juvenile fish is of concern," and that "the harvesting of (juvenile) tunas at FAD's may remove a built in safety margin that prevents growth overfishing."

A similar low-cost, low-maintenance FAD was placed in 90 m of water in Huon Gulf, northeastern P.N.G., in 1982 (and replaced in 1983), also to assist artisanal fishermen. Dried coconut fronds were attached as the attractor drape and found to be effective in attracting a variety of small baitfish species, as well as whaler sharks (Carcharhinidae), dolphin fish and tunas. The 1983 replacement FAD lasted for 22 months, and although it reduced travelling time and fuel costs, the local village fishermen were apparently not motivated enough to maintain it by regularly replacing the coconut frond drapes (Quinn, 1987).

Portable Fish Attractor

Although not a FAD in the more traditional sense, a recent Australian development termed a "fish magnet" also warrants some mention in the general category of surface fish attraction devices. This portable fish attractor consists of an inverted truncated cone-shaped structure made of heavy-duty polyethylene plastic with panels of reflective material on its submerged surfaces. Inside is mounted a rechargable battery operating a small pump which sprays water from an adjustable hose nozzle mounted above water level. When launched from a boat and floating in the water, "wave action causes the 12 mirrored panels to flash sunlight deep underwater—simulating the flanks of surface fish—while water spraying from its angled nozzle spins the buoy causing random splashing on the surface." This action is claimed to "simulate the surface disturbance of a school of anxious baitfish," and thus attract such "hungry and curious fish" and "large predators" as marlin, kingfish, dolphin fish, and various species of tunas (Anson-Smith, 1987).

Artificial Habitats for Spawning and Recruitment

Although they may not fall under the strict definition of artificial reefs or FAD's, brief mention will also be made here of a variety of artificial structures that have been used in Australian waters for small-scale experimental and other scientific studies on juvenile fish and crustacean recruitment and fish spawning.

Artificial Aquatic Vegetation

"Artificial seaweed" collectors have been used to collect the puerulus larvae (i.e., the last pelagic stage) of the western rock lobster for commercial catch prediction purposes in Western Australia since 1969 (Phillips, 1972). These collectors comprise a triangular tent-shaped structure of gray PVC sheet mounted in an aluminium frame, to which is attached seagrass matting and numerous tassels of man-made "tanikalon" fibers. They are deployed (suspended at the surface) at various points along the coastline of southwestern W.A. where the puerulus larvae, which collect among the fibers, are sampled at regular intervals. By counting the puerulus larvae which have settled, a relatively reliable estimate of the abundance of recruits to the fishery 4 years later can be made (Phillips, 1987).

Bell et al. (1985, 1987) have used "artificial seagrass units" (ASU's) to study the recruitment of postlarval and juvenile fishes and crustaceans to estuaries in the vicinity of Sydney, N.S.W. These ASU's were constructed by attaching 550 bunches each of 10 plastic "leaves" (each leaf" being 280 mm long and containing small air bubbles for floatation) to 7 m^2 panels of galvanized steel mesh using monel metal staples, giving each unit an overall leaf density of 800 m^{-2}. Twenty-four such ASU's were submerged near natural *Zostera capricorni* seagrass beds for 6 weeks, and the fish and crustaceans inhabiting them were collected using fine surrounding nets and the ichthyocide rotenone. These faunal assemblages were then compared with those collected from comparable areas within the adajacent natural seagrass beds. The ASU's yielded fewer species, but there was no significant difference in the number of individuals present. However, relative abundances of species were generally similar in the two habitats, and it was concluded that the artificial seagrass attracts vagile macrofauna typical of real seagrass, with the difference in species numbers present

probably being due to the lack of time available for the ASU's to accumulate the full suite of species present in the natural seagrass (Bell et al., 1985).

Later experiments were also carried out using similar ASU's to determine whether settling fishes discriminated between artificial seagrass with dense and sparse leaves. From these it was concluded that the relative abundances of juvenile fishes in isolated ASU's were not due to settlement preferences based on physical complexity of the seagrass habitat (Bell et al., 1987). Artificial seagrasses are also currently being used in ecological studies on the distribution and community dynamics of algae and invertebrates typically epiphytic on the seagrass *Amphibolus* in southwestern W.A. (Murdoch University, 1985).

Similar artificial macrophyte beds have also been used as "traps" in brackish and freshwater upper estuarine habitats during studies of juvenile Australian bass (Percichthyidae) recruitment in the Hawkesbury River system just to the north of Sydney. Although these units were successful in attracting a variety of small freshwater fishes, they were not judged to be very practical over longer time periods as they quickly became fouled by debris which was washed downstream[7].

Rock Shelters

Working in the freshwater riverine environment, Koehn (1987a) compared populations of river blackfish (Gadopsidae) in a stretch of the Ovens River, northeastern Victoria, which had been "seeded with large rocks," with populations in both an adjacent unmodified section and a section of the river containing willow debris. Numbers of blackfish were about nine times greater in the section containing the artificially placed rock habitat (and six times greater in that containing the willow debris) than in the adjacent unmodified section. Although Koehn noted that there appeared to be no previous documentation of the use of instream structures in attempts to enhance freshwater fish populations elsewhere in Australia, he concluded: "Overall the study highlights the importance of instream cover" . . . and "shows that the use of artificial habitat structures to increase cover can dramatically increase fish populations."

[7]J. Harris, N.S.W. Fisheries Research Institute, Cronulla. Personal commun.

Although they may not strictly qualify as artificial reefs, small pieces of eroded coralline limestone rock ("D-units") were used in comparative studies of reef fish recruitment to live coral colonies ("L-units") of similar size off Heron Island (at the southern end of the Great Barrier Reef, Queensland) by Sale and Dybdahl (1975). Greater number of species and individuals were collected (each 4 months over 2 years) from the L-units than the D-units, and although 5 common species preferred the L-units over the latter, most species did not make this discrimination. These authors concluded that, with the exception of the above 5 species, ". . . the distribution of species among units is a result of chance colonisation, not of a systematic partitioning of the living space provided."

Artificial Habitats for Spawning

With regard to artificial habitats for fish spawning, different configurations of PVC pipes have been used experimentally to provide spawning cavities for river blackfish (Gadopsidae) in freshwater stream environments in Victoria (Koehn, 1987b), and for collecting the breeding adults, eggs and larvae of introduced oriental gobies (Gobiidae) in estuaries on the N.S.W. central coast[8].

Discussion

Having outlined in some detail the history and development of various artificial fish habitat projects in the Australian region over the past 20 years or so, it is considered appropriate here to summarize some of the main problems encountered and lessons learned and to discuss possible future developments.

The most suitable materials for artificial reef construction in this region appear to vary with both the area (e.g., latitudinally) and the habitat type (e.g., estuarine vs. open ocean). For instance, while motor vehicle bodies had a life expectancy of <5 years in the subtropical waters of southern Queensland (Anonymous, 1971), in cooler temperate areas, such as the South Australian gulfs, they were found to remain substantially intact for at least 20 years[2]. In enclosed waters (e.g., estuaries and sheltered bays) bundles of motor vehicle tires appeared to provide the most suitable shelter for fish when compared with a variety of other waste materials used in the construction of multicomponent reefs (e.g., Anonymous, 1971; Beinssen, 1976). However, without substantial attachment and anchoring, such tire reefs were rapidly broken up and dispersed in more exposed situations, e.g., the South Australian gulfs (Olsen et al., 1976). In N.S.W. at least, initial studies indicate that tire reefs in the lower, more marine dominated areas of estuaries (Pollard et al., 1987) appear to support higher diversities and densities of fishes than those located in more upper estuarine situations[5].

[8]D. Pollard and R. Talbot, N.S.W. Fisheries Research Institute, Cronulla, Unpubl. data.

Some of the obvious advantages of using waste tires for reef construction include their ready availability (usually obtainable free and in large quantities), their bulk to weight ratio (and thus ease of handling and transport), their durability, and their nontoxic composition. They are also easily and cheaply attached to each other in a wide variety of configurations (e.g., using plastic packaging strap, or in more severe environments, polypropylene rope), and they provide a suitable substrate for a wide variety of sessile invertebrates and algae as well as a structurally complex habitat for fish (Beinssen, 1976; Pollard et al., 1987; and Branden[2]).

The most suitable material for reef construction in exposed or offshore areas appeared to be derelict vessels. These have proven very successful off the central coastline of N.S.W., where they are fished regularly, with good catches being taken by both recreational and commercial fishermen (N.S.W. State Fisheries, 1979). Derelict vessels have not been difficult to obtain in the vicinity of larger port cities (such as Sydney), and have usually been prepared (e.g., cleaned of oil and floatables) and transported free to the sinking site by the owners, who are eager to dispose of them cheaply. Care needs to be taken that they do not form a hazard to navigation, for which the reef-building authority could be held responsible. In

this regard, the Commonwealth Department of Transport requires 33 m depth of clear water above any vessel sunk in open ocean waters around Australia for this purpose.

Other materials which have been used successfully for reef construction in this region include large concrete pipes, quarry rock, and, in a few cases, specially constructed concrete "fish houses" and steel box frames (Beinssen, 1976). All of these materials, however, and especially when used in enclosed waters, need to be laid on very firm substrates to avoid their becoming buried. They should also be arranged on the bottom in relatively high-profile structures to be most effective in attracting and supporting significant populations of fish (Beinssen, 1976). Although specially constructed concrete "fish houses" (generally based on Japanese designs) have been used on a small scale in both subtropical and temperate areas (e.g., Davie, 1971; Beinssen, 1976), they have generally not proven to be superior to tire bundles of similar size, are more costly, and are more difficult to transport and handle.

It can thus be concluded that because of their generally low cost, ready availability, effectiveness, and relative ease of handling, waste materials, and particularly motor vehicle tires and derelict vessels, have proven to be the most popular reef building materials used in the Australian region. Although they may also prove successful, specially constructed concrete structures have been used mostly in small-scale experimental reefs constructed specifically for scientific research purposes (e.g., Russell et al., 1974).

The greatest successes to date with surface and mid-water fish aggregation devices have been achieved with either spar buoys constructed of foam-filled PVC pipe or very light and buoyant floats constructed of polyurethane foam. The former have proven to be the more suitable in high current flow areas, such as off the N.S.W. coastline (Matthews and Butcher, 1983), and the latter in other areas of lesser current flow (e.g., Anonymous, 1982b, c; Starling, 1983).

Surprisingly large anchors (up to about 1,000 kg) have been required in some areas, though railroad car wheels of around half that weight, which appear to be superior to concrete blocks, have been used successfully together with spar buoys off the N.S.W. coastline. Although both plastic-coated wire cable and chain have been used, the most successful attachment material between anchor and buoy has proven to be polyethylene rope (of either relatively short scope or weighted in places to prevent it from floating on the surface and becoming entangled in ships' propellors), together with top and bottom chains, swivels, and "hammerlock" connections.

The most successful attractor drapes appear to be "flags" of various types of synthetic mesh webbing or netting suspended within 20 m of the surface, although palm fronds suspended at or near the surface have proven both very convenient and effective in tropical areas (e.g., Quinn, 1987).

The most common groups of fishes attracted to FAD's in the Australian region, apart from a variety of pelagic bait fishes, have included various species of tunas (Scombridae) in all areas, and yellowtail kingfish (Carangidae), dolphin fish (Coryphaenidae), and various billfishes (Istiophoridae) in warm temperate to tropical waters.

In the area of portable fish attractors, the "fish magnet" (Anson-Smith, 1987) appears to show considerable promise in attracting surface-feeding fish, although its effectiveness has yet to be fully evaluated. It could also be further adapted to exploit a number of other forms of sensory stimulations of these fish, including for instance a "berley" (or "chum") slick, flashing underwater lights for night fishing, sonic attractors, etc.

Apart from the use of small concrete modules and similar artificial reef structures in experimental scientific studies (e.g., on fish recruitment), artificial vegetation (e.g., seagrass; Bell et al., 1985, 1987) also shows promise for this type of work, as do small-scale rock shelters (e.g., Sale and Dybdahl, 1975), and individual artificial spawning habitats (e.g., of PVC pipe; Koehn, 1987b), in both the inshore marine/estuarine and freshwater environments. Comparisons of natural vs. artificial reef habitats have also provided useful information on the functional ecology of these systems in the former environment (e.g., Burchmore et al., 1985).

In spite of the few relatively small-scale studies on fish recruitment and the natural-artificial reef comparisons mentioned above, and apart from the one relatively long-term ecological study of the fish assemblage inhabiting a tire reef in a N.S.W. estuary (Pollard et al., 1987), most evaluations on the effectiveness of artificial reefs and FAD's constructed in the Australian region have been based on rather haphazard observations. There is a need for more extensive and properly designed biological monitoring programs not only in Australia (e.g., Winstanley, 1979) but worldwide. As pointed out by Bohnsack and Sutherland (1985): "Due to inadequate long-term monitoring, critical knowledge about why artificial reefs work or do not work is lacking."

Some more general and summary observations based on the Australian developments described above include the following:

No large-scale "purpose built" structures (e.g., specially constructed concrete "fish houses," as used in Japan) have so far been used in production (as opposed to experimental) artificial reefs in Australia, where the emphasis has been primarily on the use of cheap and easily obtainable waste materials. Fortunately, there seem to have been few attempts to use artificial reef construction as an "excuse" for the disposal of unwanted waste materials in Australian coastal waters. Most of the production reefs constructed have been primarily for the benefit of recreational fishermen, though a number of FAD projects have been aimed at enhancing commercial (particularly tuna) fisheries.

Resources (particularly staff and funding) for artificial habitat research in the Australian region have been very restricted (compared with, even on a per capita basis, the United States and Japan). The trends in research interest up to the early 1980's were outlined by Pollard and Matthews (1985), with the majority of the publications on multi-component and tire reefs appearing around the early to mid 1970's, those on ship reefs in the late 1970's, and those on

FAD's in the early 1980's. Very little work, except for that on tire reefs in South Australia by Branden and Reimers (1987), has been carried out in Australia since that time.

At present there is no environmental "mitigation" legislation in force in Australia (e.g., along the lines of that presently applying in California: Duffy, 1985; Grant, 1987) which could provide a much-needed boost to artificial fisheries habitat construction and research here. The success of such programs in Australia to date, as in earlier times in the United States (Stone et al., 1987), has generally depended much more on the energy, enthusiasm, improvisation and initiative of those carrying them out than on specialised technical expertise and adequate funding.

In the future, with well planned and adequately funded research, it should be both technically and practically possible to design economical artificial reefs and FAD's which will be successful in attracting balanced assemblages of fishes, including harvestable populations of species of economic importance to both recreational and commercial fisheries, for use in different habitat types found around Australia.

One possibility for longer term fisheries conservation, which was discussed at the concluding session of the Fourth International Conference on Artificial Habitats for Fisheries in Miami in November 1987, is the creation of artificial habitats which might be maintained unfished. These "artificial habitat reserves" should provide protected nursery or "seeding" areas for fishes which, with increasing population numbers, would "spill over" into surrounding fished areas, thus enhancing the overall production of fisheries in the region. Before this could be successfully implemented, however, further research is needed to determine the extent to which different types of artificial habitats increase the overall biomass, rather than just concentrating populations, of economically useful species.

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NMFS Southwest Fisheries Center Marks 25th Anniversary

The Southwest Fisheries Center, a Federal research facility in NOAA's National Marine Fisheries Service, celebrated its 25th anniversary with a Rededication and Open House for the public on Saturday, 28 October 1989. The Rededication ceremony, with Roger Revelle, former Director of the Scripps Institution of Oceanography as the keynote speaker, began at 10 a.m. John Knauss, U.S. Department of Commerce Under Secretary for Oceans and Atmosphere and the Administrator of NOAA, also spoke at the Rededication.

The Center which is located at 8604 La Jolla Shores Drive, one-quarter mile north of the Scripps Institution of Oceanography, is one of only four such Federal Centers in the United States which are devoted exclusively to fisheries science research. During this Open House visitors to the Center were treated to exhibits and displays illustrating why fisheries research benefits the nation, many presented by the scientists responsible for the research involved. Among these were displays of cleared and stained "see-through" larval fish of important commercial species, models of the principal tuna species studied at the Center, plankton collecting nets and samplers, a live-fish tank, examples of the groundfish species studied, a large porpoise model exhibit, an expendable bathythermograph recorder and probe used to measure deepwater ocean temperatures, a remote-controlled underwater vehicle (ROV), a sportfishing exhibit, a panel describing the 200-mile fishing limit, and many other examples of the specialized gear and equipment used on research survey cruises. During the Open House a slide show explaining the research activities of the Southwest Fisheries Center was also shown at intervals. Videos of research conducted at sea were also seen during the day. Not least among the attractions for visitors was the view of the Pacific Ocean from the cliff-side Center, 220 feet above the water.

The parent agency of the Southwest Fisheries Center, NOAA, was established in 1970 to expand the use of ocean resources and monitor and predict conditions in the atmosphere, ocean, and space. During its first 19 years, NOAA has become an important environmental science and management agency in the Federal government. The passage of such legislation as the Marine Mammal Protection Act of 1972 and the Magnuson Fishery Conservation and Management Act has given NOAA specific responsibilities in environmental management and modified its role from that of a scientific and technical agency into one that deals with the many social, political, and economic problems of fisheries and the environment.

Also participating in the Open House were other NOAA agencies such as the National Weather Service (NWS) which has more than 300 NWS offices throughout the country to disseminate weather information. The NWS presented exhibits which included NWS radio products, current maps, radiosondes, and handouts. Also on hand to answer questions were representatives of the Office of NOAA Corps Operations which runs the agency's 23 research vessels, the National Environmental Satellite Data Information Service, and the NOAA Corps (the seventh and smallest uniformed service in the nation). NOAA is the largest agency within the U.S. Department of Commerce.

NMFS-UH Workshop Eyes Pacific Fisheries Data

Eleven fishery biologists from eight Pacific islands were in Honolulu to attend the Tropical Fisheries Resource Assessment Workshop, which ran 5-26 July 1989, announced George W. Boehlert, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory. The workshop was convened by NMFS and the University of Hawaii's School of Ocean and Earth Science and Technology, with funding provided by NMFS and the U.S. Agency for International Development.

The workshop is part of a U.S. effort to aid Pacific island nations in assessing and managing their fisheries resources. Participants are from the Cook Islands, Fiji, Kingdom of Tonga, Papua New Guinea, Solomon Islands, Tuvalu, Vanuatu, and Western Samoa.

"The workshop has brought together the best data bases for deepwater snappers in the Pacific," said Jeffrey J. Polovina, a fishery scientist with the Honolulu Laboratory and a coorganizer of the workshop, along with Richard S. Shomura, a UH researcher and former director of the Honolulu Laboratory.

Participants brought with them computer diskettes containing various types of data on the snapper fisheries in their countries. These data types include length, weight, number and species of snappers caught, as well as the amount of time spent fishing. Participants are learning data analysis techniques, many of which were developed by Honolulu Laboratory scientists over the past 5 years. One goal of the workshop was to obtain a Pacific-wide view of the potential for deepwater snapper fisheries, said Polovina.

"The snapper fisheries in some of the participating Pacific island nations are in the early stages of development," Polovina noted. "This is an excellent opportunity to monitor the stages of exploitation and ensure that snapper stocks will not be overexploited and the fisheries will not be overcapitalized."

Snappers captured by the Pacific island fishermen are sold to their local markets and, in some cases, exported to markets in Honolulu and the U.S. mainland. The increasing demand by these export mar-

kets has enabled the development and expansion of the Pacific island fisheries.

Another goal of the workshop was to predict what the maximum sustainable yield will be 5 years from now for the snapper fisheries of each Pacific island nation. (Maximum sustainable yield is how much fish can be captured each year without depleting the population.)

Workshop participants will draft reports on the condition of the snapper stocks, the maximum sustainable yield, and even how many boats should be allowed to participate in the snapper fisheries in their Pacific island nations. These reports will be given to their governments for use in managing snapper resources.

Participants are also learning various stock assessment methods and computer analysis techniques. They are participating in discussions on fishery management for snapper stocks as well as other marine species. Lectures on these topics were presented by Polovina, Shomura, Paul Dalzell from the South Pacific Commission in New Caledonia, and also other Honolulu Laboratory staff. The workshop provides participants with an opportunity to share problems related to their fisheries data collection programs. Techniques learned at the workshop will assist them in making any necessary modifications to ensure that the right kinds of fisheries data are being collected.

Interestingly, the data on bottomfish catches in the Pacific island nations participating in the workshop are generally more comprehensive that the State of Hawaii's. "Most Pacific island nations are in a much better position to manage their snapper resources than Hawaii, whose data collection is limited," said Polovina. The State of Hawaii's fisheries data collection is hampered by the lack of data on recreational fishing. The state also does not know how much time commercial fishermen spend catching snappers particularly in the main Hawaiian Islands. These types of information are crucial to the effective management of fishery resources.

NOAA Scientists Leave on 4-Month Dolphin Census

Two research vessels belonging to the National Oceanic and Atmospheric Administration (NOAA) left the San Diego, Calif., harbor on 29 July 1989 to begin another 4-month census of porpoise populations in the eastern tropical Pacific (ETP) Ocean. Scientists aboard the NOAA ships *David Starr Jordan* and *McArthur* will be busy 12 hours a day counting dolphins over 5 million square miles of sea, conducting research on dolphin populations, and providing facts that will help resolve issues relating to the incidental take of these marine mammals by the ETP yellowfin tuna fleet.

"Comparison of counts made on this cruise with counts made on other cruises using the same methods, will enable us to determine if dolphin stocks are declining and therefore in need of more protection than now exists under current regulations," says Program Leader Doug DeMaster, of NOAA's Southwest Fisheries Center in La Jolla, California. A 1984 amendment to the Marine Mammal Protection Act gave NOAA the responsibility of monitoring the relative abundance of dolphin stocks in the eastern tropical Pacific.

Because of the vast area to explore, the ships were to crisscross the ocean along different track lines, from off Baja California, Mexico, south to Peru and west to the Hawaiian Islands. The cruise is organized into four legs and will last from 29 July to 7 December with various stops throughout the Pacific.

Every scientific operation and procedure on the cruise has been carefully preplanned and will be scrupulously followed to maintain the consistency of the data that are gathered. Trained observers will be searching through special 25 × 150 binoculars for signs of dolphins, identifying species and estimating the numbers in each school. A helicopter launched from the *Jordan* will be used to photograph dolphin schools from the air, to calibrate the observers' estimates of school size. Scientific data on the physical and biological environment will also be collected, to see how environmental factors affect the distribution of dolphins in the sea.

Other "piggyback" research projects will be carried out to get maximum use of precious research vessel time. Information will be gathered on the genetic makeup and vocalization patterns of the different dolphin stocks; on the diet of sea turtles; and on the distribution of flying fish. The scientific party will also be

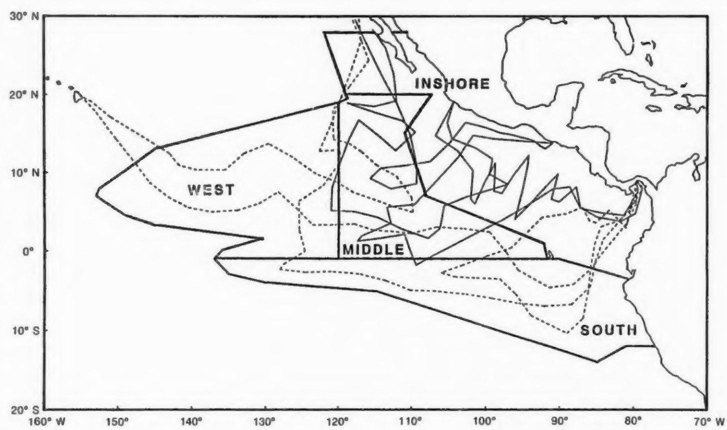


Figure 1.—Tracklines traversed by the NOAA RV *David Starr Jordan* (solid) and the *McArthur* (dashes) during the 1989 dolphin survey. Tracklines were generated using noontime positions.

monitoring populations of seabirds, sea turtles, and sea snakes along the cruise track lines.

Although scientists are impatient for the results of the dolphin monitoring program, reliable estimates of population trends will not be available until 1991. This is because rates of change in these sporadically distributed dolphin populations must be measured over a period of at least 5 years. This is the fourth in a series of six planned cruises, so final results await completion of this and two more cruises.

Certain species of dolphin associate closely with schools of yellowfin tuna, and sometimes become trapped and drown in nets set for tuna, despite fishermen's efforts to free them. Last year, 19,712 dolphins were accidentally killed in the ETP by yellowfin tuna fishermen from the United States. Under Federal law, U.S. fishermen are limited to the incidental take of 20,500 of the mammals annually. Foreign fleets that export tuna to the U.S. are now required by U.S. law to conform to similar restrictions in the mortality rates of dolphin in their catches.

The Southwest Fisheries Center in La Jolla will continue monitoring the status of dolphin populations in the ETP as well as coastal marine mammals of California, producing the most scientifically sound data possible to determine changes in population levels of these valuable living resources. The Center is a regional component of NOAA's National Marine Fisheries Service, under the U.S. Department of Commerce.

Cooperative Research Eyes Driftnet Impacts

An American scientific observer completed 28 days of research aboard a Japanese tuna drift gill-net research vessel on 30 July 1989, announced George W. Boehlert, Director of the NMFS Southwest Fisheries Center's Honolulu Laboratory. The NMFS observer, Donald Hawn, documented the kinds and numbers of animals caught by the *Kaisho Maru* and recorded other pertinent data after joining the vessel on 2 July in Kesennuma, Japan.

The impact of driftnets on high-seas resources is a topic of increasing interest. In waters north of Hawaii, fleets of fishing boats from Japan, Korea, and Taiwan are using driftnets to catch tuna, salmon, squid, and marlin. Controversy arises because the driftnets also kill marine mammals, seabirds, sea turtles, and other marine animals living in the same area as the targeted species of fish or squid.

To assess the impacts of the high-seas driftnet fleets on resources of interest to the United States, an agreement between the United States and Japan was signed in June in accordance with the 1987 Driftnet Act. The agreement called for a limited amount of cooperative catch monitoring and research during 1989. A more extensive agreement is expected next year, according to Boehlert.

As part of the accord, the United States was invited to place a scientific observer aboard a Japanese tuna driftnet research vessel to document the kinds and numbers of animals caught and to record other pertinent information. According to Hawn, the *Kaisho Maru* used about 6 miles of driftnet each night, with a mesh size ("eye") of about 7 inches, designed to catch albacore. The research vessel operated 1,500-1,900 miles northwest of Honolulu in international waters, where albacore are found near the ocean surface during the summer months.

Besides albacore, the vessel caught a variety of other species. While the vessel was in transit, Hawn and a Japanese scientist identified marine mammals in the fishing area and collected information on marine debris. They also recorded profiles of ocean temperature.

Once the data are processed, a report on the research findings will be prepared, according to Jerry A. Wetherall, a fisheries scientist who heads up the Honolulu Laboratory's Pelagic Resources Investigation as well as the driftnet research program. Wetherall noted that this was the first time the NMFS has had the opportunity to collaborate with a foreign country on a survey of driftnet fishing for tuna. Since 1986, U.S. scientists have regularly participated in research surveys by foreign driftnet vessels fishing for squid. "Because of growing concerns about the high-seas driftnets and the need to better understand their effects on marine ecosystems, more opportunities for cooperative research can be expected," Wetherall said.

Fishing Hook Removed From Tagged Monk Seal

A rather large fishing hook was removed from the mouth of a 1-year-old female Hawaiian monk seal on the south shore of Kauai over the Labor Day weekend, announced George W. Boehlert, Director of the NMFS Southwest Fisheries Center's, Honolulu Laboratory. The hook was removed from the back of the seal's jaw on 3 September 1989, by William G. Gilmartin, leader of the Honolulu Laboratory's Marine Mammals and Endangered Species (MMES) Program. Friends, campers, and fishermen in the area assisted Gilmartin by restraining the seal, which was found asleep on the beach near where she was born last year.

Removal of the hook required a large pair of pliers and a restraint time of about 10 minutes. For a short while after being released, the seal swam near shore, apparently unafraid of the people who had assisted in freeing her of the hook.

"The fishing hook, measuring 2.75 by 1.75 inches, is the size and type used while shore fishing for ulua," said Gilmartin. "The sea may have tried to take the baitfish when it was hooked, since seals commonly eat the smaller reef fishes."

This was the second attempt to remove the hook. Carrie Palama, a resident of Kalaheo, Kauai, originally reported the hooked seal to Gilmartin in mid-August. Gilmartin and Robert Morris, a veterinarian with the Makai Animal Clinic in Kailua, Oahu, flew to Kauai on 18 August to remove the hook. However, they were unable to locate the seal, probably because it was at sea. Monk seals spend most of their time at sea, generally coming to shore only to rest, give birth to their young, and to molt. The monk seal was not sighted again until she was located on 3 September.

The seal was born on Kauai on 7 August 1988, according to its tag, which NOAA scientist Thea C. Johanos had placed on the seal after it had weaned. This was the first monk seal birth re-

ported on the main Hawaiian Islands in about 10 years. Other births of this endangered species have been observed on only the small and uninhabited Northwestern Hawaiian Islands. Yet as the monk seal population in the Northwestern Hawaiian Islands increases, sightings of monk seals around the main Hawaiian Islands may increase as well, according to Gilmartin.

The Hawaiian monk seal was listed as endangered under the Endangered Species Act in 1976. Occasional beach counts of monk seals during the 1960's and 1970's indicated a drastic decline in the monk seal population. The MMES Program of the Honolulu Laboratory has been monitoring the monk seal population in the Northwestern Hawaiian Islands on a regular basis since 1982, and births have been increasing over the past few years.

To assist in the recovery of the monk seal population, the MMES Program initiated a Head Start Project in 1981 to increase first-year survival of female monk seal pups at Kure Atoll, where the monk seal population was on the verge of extinction. The pups, after weaning, are held in a wire mesh enclosure at Kure Atoll until they learn to feed on their own. The enclosure protects them pups from two sources of mortality: Aggressive adult male seals and tiger sharks, both of which are known to attack weaned pups. Female seals that were "graduates" of the Head Start Project in its early years are now giving birth. With more young females approaching reproductive age, the number of births at Kure Atoll is expected to continue to increase. Ten seals were born at Kure in 1989, compared with a low of only one in 1986.

The Head Start Project also "rehabilitates" abandoned or otherwise prematurely weaned female monk seal pups from French Frigate Shoals, where the monk seal population may be near carrying capacity. Female pups collected from the shoals are flown to Honolulu for rehabilitation and subsequently released at Kure Atoll, after being held in the protective enclosure to ensure they are able to feed on their own. This year, three rehabilitated female seals, originally captured in 1988, were added to the Kure population. They were transported by the U.S. Coast Guard to Kure Atoll in April and maintained in the protective enclosure until being released in late May.

Equal Commercial and Recreational Allocations For Atlantic Group Spanish Mackerel Okayed

Equal allocations for commercial and recreational harvesters of the Atlantic migratory group of Spanish mackerel have been approved, announced Joseph W. Angelovic, Acting Director, Southeast Region, National Marine Fisheries Service (NMFS). Reallocation procedures are contained in Amendment 4 to the Fisheries Management Plan for Coastal Migratory Pelagic Resources prepared by the South Atlantic and Gulf of Mexico Fishery Management Councils. Resulting regulatory changes become effective 19 October 1989.

According to procedures prescribed in Amendment 4 to attain 50:50 shares of the total allowable catch (TAC), allocations for the 1989-90 fishing year have been adjusted to 3.24 (commercial) and 2.76 (recreational) million pounds. Annual adjustment of allocations for the Atlantic group Spanish mackerel will continue until parity is achieved, or until 1994 when the 50:50 ratio becomes effective automatically. This will be accomplished by prorating yearly increases to TAC above the 1988-89 level of 4.0 million pounds on a 10 percent commercial:90 percent recreational basis. Decreases to TAC will be distributed based on the most current allocation ratio. The adjusted 1989-90 allocations, resulting from a TAC increase from 4.0 to 6.0 million pounds, yield a 54:46 ratio, closely approximating the 50:50 target level. When TAC reaches or exceeds 6.6 million pounds equal shares will result.

The Councils developed Amendment 4 to eliminate early season harvest closures (zero bag limits) that negatively impact the recreational sector and to remove the inequities they perceived to be associated with the previous allocation ratio (76 percent commercial:24 percent recreational). They also expect improved management of the Atlantic group Spanish mackerel to result through increasing state/Federal compatibility. As affirmed by state representatives on the South Atlantic Council, states support this 50:50 reapportionment and will respond by implementing regulations compatible to Federal law.

Study Uses Laser to Find, Identify Fish

James H. Churnside of NOAA's Environmental Research Laboratories is trying to discover if a computer-assisted laser instrument can see fish in a body of water, count them, and identify different species. If his research is successful fishermen might use airborne laser instruments to locate and quantify mature fish for commercial harvest, and immature fish could be identified for management purposes.

Churnside is examining the optical properties of various species, using an argon laser that fires a beam of blue or green light at the fish and records the reflectivity as well as the magnitude and polarization of the light. His theory is that there may be a discernible difference in the optical properties of fish by species and age, and that this could serve as a signature to their identification. The color and texture of a fish's skin would affect the optical properties, the Wave Propagation Laboratory scientist believes. Blue and green laser light passes through water more effectively than other colors and may be able to penetrate deeper into a body of water, reflecting off fish swimming beneath the surface, according to Churnside.

"Biosphere Reserve" Is Dedicated in California

Joseph A. Uravitch, Chief of the NOS Marine and Estuarine Management Division, represented NOAA at the 12 August dedication in San Francisco of the Central California Coast Biosphere Reserve. The West Coast site is the first international biosphere reserve, which encompasses marine, island, coastal, and mainland natural areas. It will provide a valuable link in a 117-country network of such reserves. The California reserve was approved in 1988 by UNESCO.

Medals Awarded by Commerce Department

In fall 1989 ceremonies, Secretary Robert A. Mosbacher presented the Department of Commerce Gold and Silver Medals to honored employees at the 41st annual honor awards program. Awarded Gold Medals were Mark E. Brown, Director, Office of Budget, Assistant Secretary for Administration; Robert P. Parker, Associate Director for National Economic Accounts, Bureau of Economic Analysis; Gerald F. Cranford, Assistant Director of Automated Data Processing, Bureau of the Census; the team of Joan M. McEntee, Deputy Under Secretary for Export Administration, Maureen R. Smith, Deputy Assistant Secretary, Philip R. Agress, International Trade Specialist, and John Richards, Deputy Assistant Secretary; Richard M. Firestone, Chief Counsel, National Telecommunications and Information Administration; and Richard Lee, Director of Science and Technology Programs, International Trade Administration.

Receiving Gold Medals in the National Institute of Standards and Technology (NIST) were George Birnbaum, Senior Scientist, Institute for Materials Science and Engineering; Lloyd A. Currie, Supervisory Research Chemist, National Measurement Laboratory; the team of Clark A. Hamilton and Richard L. Kautz, Electronics Engineers; Frances L. Lloyd, Physicist; James A. Beal, Electronics Engineer, and Richard E. Harris, Group Leader, all from the National Engineering Laboratory; the team of Donald Wayne Hanson, Supervisory Electronics Engineer; David Allan Howe, Electronics Engeiner, and James L. Jespersen, Physicist, NML; Harold E. Nelson, Senior Research Engineer, NEL; Emil Simiu, NIST Fellow, NEL; the team of Barry N. Taylor, Chief, Electricity Division, and Marvin E. Cage, Ronald F. Dziuba, Paul T. Olsen, John Q. Shields and Edwin R. Williams, Physicists, NML; and Joseph Reader, Physicist, NML.

Receiving Gold Medals in the National Oceanic and Atmospheric Administration were James V. Brosh, Chief Engineer, NOAA Corps Operations; William D. Bonner, Director, National Meteorological Center, National Weather Service; J. Michael Hall, Director, Office of Climatic and Atmospheric Research; Stanley P. Hayes, Supervisory Oceanographer, Office of Oceanic and Atmospheric Research; and Susan Solomon, Chief, Middle Atmosphere Studies, Office of Oceanic and Atmospheric Research.

Commerce Department Silver Medals were awarded to Hugh W. Knox, Chief, Regional Economic Division, Bureau of Economic Analysis; Eileen M. Albanese, Director, Special Licensing Division, and Robert F. Kugelman, Bureau of Export Administration.

Census Bureau Silver Medalists included James F. Holmes, Regional Director; Thomas L. Mesenbourg Jr., Chief, Economic Census Staff; Walter C. Odom Jr., Chief, Publication Services Division; Marvin L. Postma, Regional Director; Sylvia D. Quick, Assistant Division Chief, and Phyllis S. Willette, Section Chief.

International Trade Administration Silver Medalists included the Antidumping and Countervailing Duty Regulation Drafting Team; William D. Spitler, Supervisory Trade Specialist; Barbara A. Steinbock, Legislative Coordinator; and Timothy P. Stratford, Commercial Officer.

Silver Medal honorees in the National Oceanic and Atmospheric Administration included Richard G. Bakkala, Supervisory Fishery Biologist, National Marine Fisheries Service; Dennis M. Decker, Meteorologist, National Weather Service; Atef A. Elassal, Chief, Photogrammetric Technology Programs; Gary K. Grice, Assistant Chief, Meteorology Services Division; Kenneth W. Howard, Stanley L. Barnes, and Charles A. Doswell III, Meteorologists, Oceanic and Atmospheric Research; Mary M. Heffernan and Edward R. Johnson, Branch Chief, NWS; Milan A. Kravanja, Chief, Foreign Fisheries Analysis Branch, Office of International Affairs, NMFS; Ronald C. Lundstrom, Research Food Technologist, National Marine Fisheries Service; E. Paul McClain, Physical Scientist, National Environmental Satellite, Data, and Information Service; Edward J. McKay, Chief, Vertical Network Branch, NOS; Roy Mendelssohn, Operations Research Analyst, National Marine Fisheries Service; Earl F. Prentice, Supervisory Fishery Biologist, NMFS; Arthur Schwalb, Chief, Space Systems Division; NESDIS; Robert C. Sheets, Director, National Hurricane Center, and Robert A. Case, Gilbert B. Clark, Harold P. Gerrish, James M. Gross, Miles B. Lawrence and B. Max Maxfield, Hurricane Specialists, NWS; Wilbur T. Shigehara, Meteorologist-in-Charge, NWS; and George W. Swearingen, senior electronics technician, NWS.

Earning Silver Medals in the National Telecommunications and Information Administration were Robert T. Adair, Group Chief, and Daivd F. Pech, Electronics Engineer; Dennis R. Connors, Director, Jean E. Adams, Supervisory Electronics Engineer, and Joann C. Anderson and Richard P. Harland, Communication Program Specialists, and James T. Vorhies, Communication Management Specialist. Medalists in the Office of Inspector General were Charles M. Hall, Assistant Inspector General for Inspections and Resource Management; Carl S. Klein, Supervisory Auditor, and Irene E. Lewkowicz, Director, Science and Trade Division. Medalists in the Patent and Trademark Office were Howard N. Golberg, Supervisory Patent Examiner, and Steward J. Levy, Supervisory Patent Examiner.

Silver Medalists in the National Institute of Standards and Technology were the team of Ramon C. Baird, Chief, Electromagnetic Fields Division; Michael H.

Francis, Physicist; Douglas P. Kremer, Supervisory Electronics Technician; Allen C. Newell, Supervisory Physicist, and Andrew G. Repjar and Carl F. Stubenrauch, Electronics Engineers, NEL; Carroll S. Brickenkamp, Supervisory Physical Scientist, Office of the Director; Richard E. de la Menardiere, Chief, Acquisition and Assistance Division, Office of Director of Administration; Dale D. Hoppes, Supervisory Physicist, NNL; Motohisa Kanda, Group Leader, NEL; Yong-Ki Kim, Supervisory Physicist, NML; Roger J. Martin, Supervisory Computer Scientist, National Computer Systems Laboratory; George E. Mattingly, Supervisory Mechanical Engineer, NEL; Bruce R. Miller, Physicist, NEL; Nile M. Oldham, Physicist, NEL; E. Neville Pugh, Chief, Metallurgy Division and Ugo Bertocci, Research Chemist, Institute for Materials Science and Engineering; William P. Reed, Deputy Chief, Office of Standard Reference Material and John A. Norris, Research Chemist, NML; the Reactor Operations Group, Institute for Materials Science and Engineering; and Miles E. Smid, NCSL.

Origin of Fish Taken in Sting Operation Determined

Genetic tests and an examination of scales of steelhead trout taken from Taiwanese driftnet vessels during a recent high-seas "sting" operation prove that the fish came from North America, according to the National Oceanic and Atmospheric Administration (NOAA). The fish were seized by agents of NOAA's National Marine Fisheries Service (NMFS) during the largest covert fisheries operation in U.S. history. The fish were examined by scientists at the NMFS Northwest Fisheries Center and the University of Washington in Seattle to determine their continent of origin.

A Taiwanese businessman, Patrick Lee, has been charged with masterminding the sale of 550 tons of the U.S.-spawned salmon to NOAA undercover agents. Lee was arrested 19 July as he walked out of a Seattle bank vault carrying suitcases holding more than $1 million in cash. Others have since been taken into custody. It is illegal to catch U.S.-spawned salmon in North Pacific driftnet fishing operations.

Results show that three of the four steelhead examined came from North America. Two had their adipose fins clipped, identifying them as North American hatchery fish. Another contained a parasitic flatworm in its kidney that identified its home stream as somewhere between northern California and southern Puget Sound. The origin of the fourth steelhead could not be established. A team of NOAA scientists went to Kaohsiung, Taiwan, to conduct a more extensive sampling of the catches of the two Taiwanese driftnet vessels to determine more accurately the continent of origin of the fish, and their results will be reported later.

Sharks to Come Under Management in U.S. Atlantic Ocean Waters

Shark resources are valuable to many user groups, ranging from consumers of shark meat in the U.S. to consumers of sharkfin soup in the Orient, recreational fishermen who enjoy catching sharks on rod and reel, andmedical researchers studying cancer.

"Sharks have existed for over 400 million years but are in trouble in U.S. Atlantic waters, including the Gulf of Mexico and Caribbean Sea," said Joseph Angelovic, Acting Southeast Regional Director, National Fisheries Service, responsible for the development of a shark management plan for the Secretary of Commerce under provisions of the Magnuson Act. "They have been overfished for over 10 years and because of their unique biology we are fearful of a stock collapse."

Sharks are unlike most fish that produce millions of eggs. They grow slowly, take many years to reach maturity, and produce only a few young, generally 2-25 pups, after long reproductive cycles. The maximum sustainable yield from U.S. waters is estimated to be 16,250 metric tons (t) annually. Shark mortality, sharks landed or discarded dead, has surpassed maximum sustainable yield by about 5,900 t annually over the past 10 years. A draft Secretarial Shark Fishery Management Plan has been prepared for public review and comment. In addition 22 public hearings were scheduled to receive comment on the plan.

The plan would bring 38 species of shark under management. The management measures would: Establish a commercial quota of 5,800 t; establish a recreational bag limit of one shark per person per day in the U.S. Exclusive Economic Zone; establish a procedure for adjusting annual harvest levels for commercial fishermen and bag limits for recreational fishermen; prohibit "finning" by only allowing fins to be landed in proportion to carcasses, i.e., no more than four fins per carcass; prohibit sale of recreational catch; require annual permits for commercial shark fishermen, i.e., fishermen who harvest and sell shark meat and fins; require annual permits for dealers; and require monthly reports by permitted commercial fishermen and dealers, and by persons conducting tournaments. After public comments are considered, the plan will be finalized and if approved by the Secretary of Commerce, may be implemented in July 1990.

Ground Broken for New Sandy Hook Laboratory

A groundbreaking ceremony was held at Sandy Hook, New Jersey, on 11 October 1989 to mark construction of a 36,000-square-foot marine research laboratory to be occupied by scientists from the NMFS Northeast Fisheries Center and from state agencies and academic institutions in New Jersey. The new laboratory, to be completed in about 3 years and named the James J. Howard Marine Sciences Laboratory to honor the late U.S. Representative from New Jersey who strongly supported marine research, is a response to a 21 September 1985 fire which leveled one of the two buildings comprising the old NMFS Sandy Hook Laboratory.

The new laboratory, to be funded by the state with space leased to the Center, will house experimental seawater and

analytical chemistry laboratories. As part of the construction package, the one remaining building of the old Sandy Hook Laboratory (a designated national historic building) will be rennovated for library, conference room, and light lab use.

NMFS Beaufort Laboratory Celebrates 90th Anniversary

The NMFS Southeast Fisheries Center's Beaufort, N.C., Laboratory celebrated its 90th Anniversary during 1989. The lab was established in 1899 by the U.S. Commission of Fish and Fisheries to study the biology and relationship of marine animals and plants, their environment and fisheries potential. The Laboratory is the nation's second oldest Federal Fisheries Laboratory. An open house was held 20 October and a banquet on 17 November. The National Sea Grant representative presented Ford A. Cross, Laboratory Director, a plaque congratulating the Lab on its many accomplishments and acknowledging the close association that exists between the Lab and Sea Grant.

NOAA, UMass, URI Share Operations

The National Oceanic and Atmospheric Administration (NOAA) and each of the Universities of Massachusetts (UMass) and Rhode Island (URI) have begun a formal program to share scientists and resources for studying timely marine issues. Called the Cooperative Marine Education and Research (CMER) Program in each case, the partnership with UMass is now undertaking five research projects, and with URI two projects, involving NOAA's NMFS Northeast Fisheries Center.

The NOAA/UMass CMER's five fisheries-related projects ultimately seek to: 1) Reduce chances of rancidity in frozen Atlantic mackerel, 2) develop uses for wastes from mackerel processing, 3) determine if skates out-compete traditional groundfishes (e.g., haddock) for prey during early life stages, 4) understand better the spawning and early development of skates, and 5) relate movements of northern right whales to environmental conditions (e.g., water temperatures).

The NOAA/URI CMER's two fisheries-related projects involve: 1) An economic analysis of the U.S. market for blue mussels and 2) a better understanding of the seasonal and areal changes in abundance of the coastal Gulf of Maine's *Calanus* spp. copepods, a major prey for many of the Gulf's economically important fish species.

New Genus, Two New Species of Box Crabs

Exploratory trawling with the old Bureau of Commercial Fisheries research vessels *Pelican*, *Combat*, *Silver Bay*, and *Oregon*, and with the NOAA research vessel *Oregon II*, yielded large collections of decapod crustaceans which were stored at the National Museum of Natural History. Recent study of those crustaceans has produced one genus (*Cyclozodion*) and two species of box crabs (family Calappidae) in the Northwest Atlantic new to science. For further information, contact Austin B. Williams, FTS (202) 357-2639 at the NMFS National Systematics Laboratory.

Cooperative Research Institute Established

NOAA and the University of Michigan have established a new Cooperative Institute for Limnology and Ecosystem Research, to be based at the university in Ann Arbor. Alfred Beeton, Director of NOAA's Great Lakes Environmental Research Laboratories in Ann Arbor, Mich., said the new institute will conduct Great Lakes-related research involving both university and NOAA scientists. Activities will be in the areas of toxic contaminants and chemical processes, coastal hydrodynamic and sedimentary processes, water quality and lake levels, physical processes, ecosystem dynamics and habitat, and climate and global change.

The institute has been established in cooperation with Michigan State University, and is unique in that it will provide for the participation in the research program of researchers at any Great Lakes Basin institution. The institute is the seventh established by NOAA with universities throughout the United States, and it is the only one with a primary focus on the Great Lakes.

NOAA Selects Great Bay As a Research Reserve

The National Oceanic and Atmospheric Administration (NOAA) designated 4,471 acres of land and tidal waters in and around Great Bay, N.H., as the Great Bay National Estuarine Research Reserve in October 1989. The new Reserve encompasses all water areas of Great Bay, including 48 miles of shoreline, the bay's tidal waters and mudflats, and the Winnicut, Squamscott, and Lamphrey river channels, plus five key upland areas around the estuary. This is the nation's eighteenth estuarine research reserve.

The National Estuarine Research Reserve System, administered by NOAA's Marine and Estuarine Management Division, includes unique sites representative of biogeographical regions of the country. A state-Federal matching-fund program, establishment of the Reserve makes New Hampshire eligible for financial support from NOAA for estuarine research and development of educational programs for the Great Bay area, and to support management staff. NOAA and New Hampshire also supported acquisition of key land areas to establish the reserve.

Italy-U.S. Fish Trade, 1981-88

Introduction

Italy is the world's fourth largest importer of fishery products, surpassed only by Japan, the United States, and France. The value of Italy's fishery imports has more than doubled from $0.7 billion in 1981 to $1.8 billion in 1987. Imports now constitute a larger proportion of Italian consumption of fishery products than does the domestic catch. The latter has increased only gradually since 1981. Italian fishery exports have not kept pace with imports; therefore, the trade deficit in fishery products has increased from $0.6 billion in 1981 to $1.6 billion in 1987.

Although the United States ranks among the world's leading exporters of fishery products, its share of the Italian import market has traditionally been less than 1 percent. In 1988, however, U.S. fishery exports to Italy doubled in value compared with those in 1987 and trebled in quantity. On the other hand, U.S. fishery imports from Italy, never a significant share of the U.S. market, decreased from $4 million in the mid-1980's to only $3 million in 1988[1].

Background

Italy's fisheries sector was mostly an artisanal operation as late as the 1930's. After the widespread destruction during World War II, the fishing industry was rebuilt and modernized along with the rest of the country. Over the past 20 years, the modernization of the fishing industry has continued. The fleet has expanded appreciably since the 1960's: The number of engine-powered vessels has doubled, while the total engine power of the fleet has trebled. The fishing fleet is now the second largest in the European Community (EC) after Spain's. The majority of Italy's 20,000 vessels are trawlers under 50 gross registered tons (GRT), operating mostly in the Mediterranean and the Adriatic. Other types of vessels fishing in the Mediterranean are equipped with multiple gear, purse seines, or dredges (for harvesting bivalve mollusks). While the number of small vessels has increased in recent years, the number of larger high-seas vessels has declined from over 50 to about 30 vessels for reasons discussed below. The remaining high-seas vessels, each over 500 GRT, fish in the Atlantic and Indian Oceans.

Italian fishermen, like fishermen in other countries, faced two adverse international conditions in the 1970's: Increasing fuel prices and decreasing access to many traditional distant-water fisheries, following the implementation of 200-mile Exclusive Economic Zones (EEZ's). The loss of these distant-water fisheries severely affected fishermen in Italy. They had begun to rely on North and West African fishing grounds because Italian coastal grounds were overfished and polluted.

During the late 1970's, well-organized fishery cooperatives pressured the Italian government for aid, claiming that high fuel costs and longer fishing voyages made it uneconomical for them to compete with fishery imports. Initially, the government provided only fuel subsidies, but soon it adopted more comprehensive measures. In 1982, the government introduced a $50 million, 3-year "Plan for Rationalization and Development of Italian Marine Fisheries," designed to restructure Italy's fishing industry. To compensate for the loss of distant fishing grounds and for increasing operating costs, the plan provided for 1) modernization of the fishing fleet by subsidizing the replacement of old vessels, 2) joint ventures between Italian and foreign fishing companies, 3) bilateral agreements with nations off

[1]Significant U.S. imports of "nonedible partial fishery products," mostly jewelry, are not considered in this report. In 1988, these imports amounted to $1,088 million.

whose coasts Italian fishermen had operated prior to the EEZ extensions, and 4) exploratory fishing in unexploited fishing grounds. The Plan produced good results: Many older vessels were scrapped, joint ventures were created (with U.S. fishermen, for example[2]), and fishing agreements with West African countries have been signed (through the European Community). The continuing increase of Italian fishery imports during the 1980's, however, indicates that Italian fishermen have not been able to keep pace with domestic demand for fishery imports.

Italian law requires the formulation of a new national plan for fisheries every 4 years. The current plan (1987-90) emphasizes conservative resource management: Reduced trawling in the Mediterranean, reduced fishing for venus clams, and no increase in fishing for demersal species. One important objective, which several other EC nations share, is to gradually reduce the size of the fishing fleet. Italy plans to decrease the tonnage of its fleet (about 262,000 GRT) by 5 percent before 1990.

In spite of government development plans, part of the fishing industry, particularly in southern Italy, has modernized only slowly, retaining many of its artisanal aspects. Many fishermen sell their catch directly to customers, avoiding official markets. Products sold in this manner are probably not included in government fisheries catch or consumption figures. Thus, official statistics concerning both catch and sales of fishery products are suspect. Informed observers have estimated that as much as one-third of the Italian fisheries catch goes unreported.

Despite their well publicized difficulties, Italian fishermen have doubled their catch over the past 3 decades. The catch continued to increase until 1985, when 583,000 t of fish, shellfish, and other aquatic products were harvested; this total decreased to 554,000 t in 1987, the last year for which the data were available (Fig. 1). The diversity of the

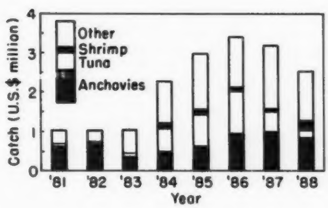


Figure 1—Italy's fisheries catch, 1981-88.

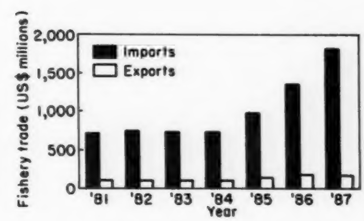


Figure 2.—Italy's fishery imports and exports by value, 1981-87.

catch has allowed fishermen to concentrate on new species as stocks of traditional species have declined. Harvests of some important species have increased recently: Mussels (now the most important species by quantity) from 58,000 t in 1981 to 85,000 t in 1987[3], European hake from 15,000 t to 27,000 t, venus clams from 21,000 t to 37,000 tons. The catch of two important Mediterranean species, however, has decreased significantly: The pilchard catch declined from 78,000 t in 1981 to 47,000 t in 1987, while the harvest of anchovies has decreased from 61,000 t to 20,000 tons. The pelagic catch[4] declined mainly because the use of nets having a mesh smaller than the legally allowed 4 cm has depleted immature fish. In addition, the domestic demand for these species has decreased.

Fisheries Trade

Italy's trade deficit in fishery products increased from $600 million in 1981 to over $1,600 million in 1987 (Table 1). Over that period, the value of exports varied from $100 million to $180 million, while imports increased from $720 million to $1,800 million (Fig. 2).

Imports

Since 1981, Italy has increased its imports of traditionally popular fishery products—tuna, hake, dried and salted cod, and groundfish fillets—and has

Table 1.—Italy's balance of trade in fishery products, by value, 1981-87 (1988 data not yet available)[1].

	Trade (US$ millions)		
Year	Exports	Imports	Bal. of trade
1981	106.7	720.2	−613.5
1982	101.5	752.8	−651.3
1983	104.5	735.4	−630.9
1984	104.9	742.1	−637.2
1985	140.9	985.0	−844.1
1986	183.4	1,360.6	−1177.2
1987	174.4	1,824.0	−1649.6

[1]Sources: FAO Yearbook of Fishery Statistics—Commotidies, var. years; European Supply Bulletin, Dec. 1988.

supplemented these with additional and growing imports of shellfish[5]—squid, shrimp, and lobster (Fig. 3). In 1986, Italy was the world's second largest importer of squid (behind Japan) and the third largest importer of tuna (behind Japan and the United States). Tuna imports, some of which are canned for reexport, increased from 50,000 t in 1981 to 114,000 t in 1987, when they were valued at $170 million. Squid imports almost trebled over the same 7 years from about 25,000 t to 71,000 t worth $100 million. Shrimp imports increased from 6,200 t in 1981 to 17,000 t, worth $134 million, and lobster imports, under 300 t in 1981, reached 3,600 t in 1987.

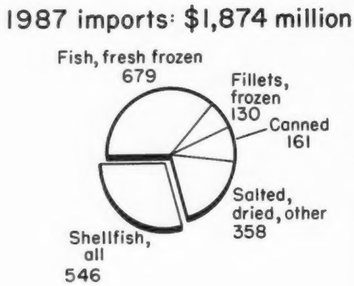
Italy's most important suppliers of fishery products are EC member countries. For example, France and Spain supply most fresh and frozen tuna,

[2]There were several joint ventures between Italian and U.S. fishermen in the 1980's, but these no longer operate; U.S. fisheries have been gradually "Americanized" since the mid-1980's.

[3]Partially from increased mussel aquaculture.

[4]Pilchards, sardines, anchovies, and other pelagic species are collectively called "blue fish" (pesce azzurro) in Italy.

[5]In this report, shellfish includes cephalopods (such as squid), following the classification used by the Organization for Economic Cooperation and Development (OECD).



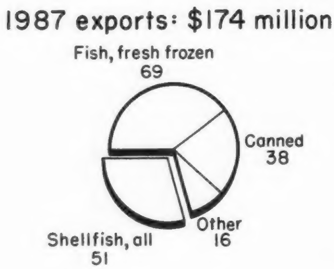


Figure 3.—Italy's imports and exports of fishery products by commodity and value, 1987.

while Spain exports mussels; the Netherlands supplies frozen plaice fillets and the Federal Republic of Germany (FRG) exports canned fillets.

Imports from EC nations are favored because they are exempt from the tariffs (ranging from 5 to over 15 percent by value) which are assessed on fishery imports from non-EC nations. Northern Europe's well-developed transportation system allows the EC member countries to supply Italy's growing market for fresh fish. Importers in Milan, northern Italy's main distribution center for West European fishery products, have reported that fresh fish from abroad often arrives more quickly than fish from Sicily. For example, fish landed in Danish ports can be refrigerated, transported overland across the FRG and Switzerland to Milan, and sold fresh within 3 days after being landed. Italian products, on the other hand, often take a circuitous route to the market: They are first frozen and stored, then later thawed and sold as "fresh" fish. Imported fish has thus become associated with higher quality.

Several non-EC nations are also important suppliers to Italy: Norway (which qualifies for reduced tariffs because of its fishing agreements with the EC) is a major source of salted cod. Poland and Thailand are Italy's largest suppliers of squid, together providing over half of squid imports in 1987 (19,000 t and 17,000 t, respectively). Argentina is Italy's largest source of hake (7,000 t out of 18,000 t in 1987), and Cuba is an important supplier of shrimp (2,000 t out of 17,000 tons).

Italy has strict and vigorously enforced health regulations for imported fishery products. Imports must be accompanied by a health certificate—printed in Italian as well as in the language of the country of origin—identifying the product, certifying that it has been suitably refrigerated or frozen, specifying any chemical additives used, and stating that the product is wholesome and fit for human consumption.

The Italian government has implemented additional health regulations because of concern over heavy-metal contamination in seafood. All fishery imports must be accompanied by a certificate of mercury content, released by the appropriate authorities of the exporting country, testifying that the mercury content does not exceed 0.7 mg/kg (or parts per million). According to the U.S. Embassy in Rome, the Italian Ministry of Health has divided fish species into 2 main categories depending on whether they tend to have low or medium-to-high mercury content. Most species—including U.S. Pacific salmon, pelagics such as herring and anchovy, shellfish such as squid, shrimp, lobster and crawfish—are classed as "low mercury content." For these species, the Ministry will accept a general statement by the authorities of the exporting country that, "the shipment of fish does not have a mercury content higher than 0.7 mg per kg." For medium-to-high risk fish—including tuna, swordfish, and several species of sharks—a detailed mercury content certificate must accompany each shipment to Italy.

The government has also placed specific restrictions on some shellfish imports. After imported squid was found to contain significantly more than the 2 mg/kg limit of cadmium, the Italian Government began restricting squid imports to entrails-free product only. (Although the entrails were not intended for human consumption, there was concern that they could contaminate fish meal or other products.) Italy also temporarily restricted imports of clams from Thailand because of contamination. Imported clams and oysters now must come from approved fishing areas, and importers must have purification facilities.

Exports

Italy's exports of fishery products are significant but they have not increased in proportion to fishery imports (Fig. 2 and 3). Export value remained at about $100 million per year during 1981-84, increased to a high of $180 million in 1986, but declined in 1987 (Table 1). The largest exports are fresh, frozen, and canned sardines and anchovies ($32 million in 1987). Other exports include squid ($26 million), trout ($12 million), canned tuna ($12 million), and mussels ($2 million). The bulk of Italy's exports are sold to other EC nations, primarily to nearby France and Spain.

U.S.-Italy Fisheries Trade

The turnover value of U.S.-Italian fisheries trade (imports and exports) has increased from $5.5 million in 1981 to $17.5 million in 1988. Each country remains only a minor fisheries trading partner for the other. U.S. fishery exports to Italy represented less than 1 percent of total Italian fishery imports in the 1980's (Table 2). U.S. fishery imports from Italy were an even smaller share of U.S. fishery imports, well under 0.1 percent of the total.

U.S. fishery exports to Italy are modest compared with U.S. exports to other EC nations. In 1988, the United States exported $265 million to the EC, 70 percent of which was bought by the UK, France, and the Netherlands (Table 3). Although U.S. fishery exports to Italy increased significantly in 1988, surpassing

Table 2.—Italy's fishery imports from the United States compared with total imports, by value, 1981-88[1].

Year	Imports (US$ millions) Total	U.S.	U.S. share[2] (Percent)
1981	720.2	4.5	0.6
1982	752.8	8.1	1.1
1983	735.4	5.5	0.7
1984	742.1	4.0	0.5
1985	985.0	3.4	0.3
1986	1,360.6	4.3	0.3
1987	1,824.1	6.6	0.4
1988	N/A[3]	14.9	N/A

[1]Sources: FAO Yearbook of Fishery Statistics—Commodities, var. years (for total imports); the U.S. Bureau of the Census (for imports from the United States).
[2]Imports of fishery products from the United States as a percentage of Italy's total fishery imports.
[3]N/A = Data not yet available.

Table 3.—U.S. exports of fishery products to member states of the European Community (EC), by value, 1981-88[1].

Country	Exports (US$ millions) 1981	1982	1983	1984	1985	1986	1987	1988
UK	105.6	46.9	73.6	61.2	51.9	77.3	72.6	81.6
France	60.0	52.7	35.5	34.3	30.6	52.3	72.9	71.8
Netherlands	32.2	26.2	35.6	60.1	34.4	26.0	32.2	33.5
Italy	4.5	8.0	5.5	4.0	3.3	4.3	6.6	14.9
FRG	22.1	10.9	26.9	12.6	11.0	7.9	11.8	13.2
Belg./Lux.	19.8	15.9	11.4	13.1	8.4	10.7	11.9	12.0
Portugal[2]	3.0	3.6	4.3	2.3	2.5	0.8	3.0	11.9
Denmark	3.4	3.7	4.1	4.8	7.3	5.3	7.1	10.3
Spain[2]	1.8	2.5	4.3	1.5	0.7	5.4	3.6	9.4
Greece	4.5	3.5	0.8	0.3	1.0	2.5	2.0	5.6
Ireland	1.4	0.4	0.6	0.8	0.8	0.6	0.4	0.3
Total	258.3	174.3	202.6	195.0	151.9	193.1	224.1	264.5

[1]Source: U.S. Bureau of the Census.
[2]Spain and Portugal became members of the EC in January 1986.

Table 4.—U.S. fishery exports to Italy compared with fishery exports to the EC, in percent, 1981-88[1].

Year	Exports (US$ millions) Italy	Total EC	Italian share (Percent)
1981	4.5	258.3	1.7
1982	8.0	174.3	4.6
1983	5.5	202.6	2.7
1984	4.0	195.0	2.0
1985	3.3	151.9	2.2
1986	4.3	193.1	2.2
1987	6.6	224.1	2.9
1988	14.9	264.5	5.6

[1]Source: U.S. Bureau of the Census.

Table 5.—U.S. fishery exports to Italy, by commodity and value, 1981-88. U.S. Census Bureau data.

Commodity	U.S. exports to Italy (US$1,000) 1981	1982	1983	1984	1985	1986	1987	1988
Edible								
Fish								
Salmon								
Chinook	1,292	963	301	838	309	274	109	1,045
Chum	159		891	299	54	122	52	212
Other	481	1,104	437	839	457	392	237	653
Canned	208	431	479	406	452	188	76	352
(Salmon total)	(2,140)	(2,498)	(2,108)	(2,382)	(1,272)	(976)	(474)	(2,262)
Eels	516	219	153	79	90	92	730	1,491
Roe (not salmon)	30	72	174	103	396	761	1,518	303
Mackerel		23	48	19			14	
Mullet								63
Cod								36
Other fish	1,203	4,315	1,300	529	414	733	1,021	2,140
Subtotal	3,889	7,127	3,783	3,112	2,172	2,562	3,757	6,295
Shellfish								
Squid[1]								
Loligo, frozen	101	574	1,019	398	998	606	947	2,117
Other, frozen						466	1,092	3,761
Canned		14	124					165
(Squid total)	(101)	(588)	(1,143)	(398)	(998)	(1,072)	(2,039)	(6,043)
Lobster						23	7	1,105
Shrimp								
Fresh/frozen	10	191	15	13		4	4	200
Canned	2		22	115	15	10	40	39
Crab	114	115	2		7	4		64
Sea urchin						11		45
Clams, frozen						7		20
Other shellfish								
Fresh/chilled	225	16	218	256	114	456	573	724
Frozed/cured	7	3	326	59	1	37	117	271
Subtotal	459	913	1,726	841	1,135	1,624	2,780	8,511
Subtotal (edible)	4,348	8,040	5,509	3,953	3,307	4,186	6,537	14,806
Inedible								
Shells	108	44	7	42	53	19	54	106
Fish/marine oils	40				1	47	4	6
Fishmeal				Negl.[2]		1	2	15
Seaweed						1	2	2
Subtotal (inedible)	148	44	7	43	54	68	62	129
Grand total	4,496	8,084	5,516	3,996	3,361	4,254	6,599	14,935

[1]Squid statistics are not differentiated by species before 1986.
[2]Negl. = Value less than $1,000.

those of Denmark, the FRG, and Belgium/Luxembourg, they still accounted for less than 6 percent of exports to the European Community (Table 4).

U.S. Exports

U.S. fishery exports to Italy more than doubled in 1988 to $14.9 million, compared with $6.6 million in 1987 (Table 5, 6). Squid exports increased most dramatically: From $2 million in 1987 to $6 million in 1988, when they accounted for 40 percent of the value of U.S. fishery exports to Italy. Salmon exports recovered in 1988 to $2.3 million after declining for several years to only $0.5 million in 1987. Eel exports have also recovered, from under 30 t in the mid-1980's, to 400

Table 6.—U.S. fishery exports to Italy, by commodity and quantity, 1981-88. U.S. Census Bureau data.

Commodity	Exports (metric tons)							
	1981	1982	1983	1984	1985	1986	1987	1988
Edible								
Fish								
Salmon								
Chinook	149	113	40	115	46	45	14	81
Chum	43		216	79	17	42	8	44
Other	262	159	102	222	97	70	46	69
Canned	47	128	155	129	95	73	29	101
(Salmon total)	(501)	(400)	(513)	(545)	(255)	(230)	(97)	(295)
Eels	186	106	68	21	40	22	244	399
Roe (not salmon)	2	2	16	6	32	56	94	18
Mackerel		52	91	34			20	
Mullet								19
Cod								15
Other fish	271	3382	695	244	516	427	333	1,228
Subtotal	960	3,942	1,383	850	843	735	788	1,974
Shellfish								
Squid[1]								
Loligo, frozen	62	396	541	231	839	348	554	1,445
Other, frozen						212	334	1,860
Canned		13	81					111
(Squid total)	(62)	(409)	(622)	(231)	(839)	(560)	(888)	(3,416)
Lobster						2	1	105
Shrimp								
Fresh/frozen	1	42	1	2		Negl.[2]	Negl.	35
Canned	Negl.		4	21	3	2	6	4
Crab	12	8	Negl.		1	Negl.		23
Sea urchin						1		3
Clams, frozen						3		6
Other shellfish								
Fresh/chilled	25	2	119	108	47	198	218	155
Frozed/cured	1	1	95	9		5	62	134
Subtotal	101	462	841	371	890	772	1,176	3,881
Subtotal (edible)	1,061	4,404	2,224	1,221	1,733	1,507	1,964	5,855
Inedible								
Shells	38	24	2	30	55	9	12	24
Fish/marine oils	36				Negl.	36	Negl.	Negl.
Fishmeal				Negl.		8	Negl.	201
Seaweed						Negl.	1	Negl.
Subtotal (inedible)	74	24	2	30	55	53	13	225
Grand total	1,135	4,428	2,226	1,251	1,788	1,560	1,977	6,080

[1]Squid statistics are not differentiated by species before 1986.
[2]Negl. = Value less than 1 metric ton.

t, worth $1.5 million in 1988 (Fig. 4).

The mid-1980's decline of U.S. fishery exports to Italy, like the overall decline of U.S. fishery exports to the EC, can be partially attributed to the strength of the dollar. The value of the Italian lira decreased 40 percent against the dollar from 1981 to 1985, when Italian imports from the United States reached a low point. Since 1985, Italian imports have increased again, as the lira regained much of its former value (Fig. 4, 5).

The increased U.S. squid exports to Italy in 1988 coincided with the increase in total U.S. squid exports. During that

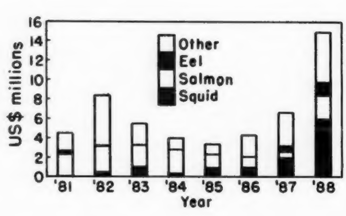


Figure 4.—Italy's fishery imports from the United States by commodity and value, 1981-88.

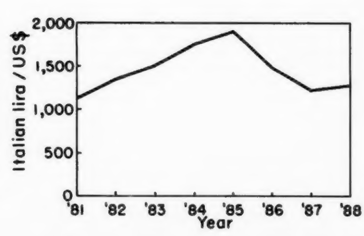


Figure 5.—Exchange rate, Italian Lira:U.S. dollar, 1981-88.

Table 7.—U.S. fishery exports to Italy, by commodity and value, 1981-88. U.S. Census Bureau data.

	Imports (US$1,000)							
Commodity	1981	1982	1983	1984	1985	1986	1987	1988
Edible								
Fish								
Anchovies, canned	652	727	388	526	651	974	1,023	870
Tuna								
Fresh/frozen	2			509	733	929	358	50
Canned	49	16	29	31	35	99	118	108
(Tuna total)	(51)	(16)	(29)	(540)	(768)	(1,028)	(476)	(158)
Sardines, canned	136	30	44	156	598	164	219	74
Surimi						50		42
Salmon	1			1	13	15	19	9
Shark fins							16	6
Other fish	72	19	87	157	204	520	276	397
Subtotal	912	792	548	1.380	2,234	2,751	2,029	1,556
Shellfish								
Shrimp, fresh/frozen			44	176	162	134	97	281
Clams								
Fresh/frozen			27	2	3	26	16	1
Canned	15	46	142	239	190	49	47	63
(Clam total)	(15)	(46)	(169)	(241)	(193)	(75)	(73)	(64)
Crabs, fresh/frozen				14	8		13	12
Squid						2	10	4
Other shellfish	59	22	45	111	48	18	54	1
Subtotal	74	68	258	542	411	229	237	362
Other								
Antipastos			162	276	232	376	482	484
Soup preparations							17	16
Frogs							4	
Subtotal (edible)	986	860	968	2,198	2,877	3,356	2,769	2,418
Inedible								
Sponges	6	27	32	43	44	24	210	82
Fish oils					1	2	10	2
Shells	7	15	1	16	10		6	
Other inedible[1]	33	128	43	7	44	20	13	28
Subtotal (inedible)	46	170	76	66	99	46	239	112
Grand total	1,032	1,030	1,044	2,264	2,975	3,402	3,008	2,530

[1]Primarily coral.

year, the United States exported 17,000 t worth $25 million, or more than double the 1987 squid export level. Several factors (besides the improved exchange rate) favored increased exports to Italy. First, average prices of U.S. squid exports to Italy decreased from $2.30/kg in 1987 to $1.80/kg in 1988. Second, U.S. squid-fishing and processing has improved. There are now over 10 American freezer-trawlers fishing for squid off the Atlantic coast. The "Americanization" of the U.S. squid fishery phased out Italian fishermen who used to fish in U.S. waters under joint-venture agreements. Italy imports U.S. squid partly to make up this loss. Third, fishermen off the Falklands Islands, a prime squid fishery, reported difficulty catching longfin squid, *Loligo pealei*, in 1988. Low prices made fishing for shortfin squid, *Illex illecebrosus*, off the Falklands unprofitable, because of license and transportation costs. In short, increased U.S. supply, improved quality, and reduced price promoted U.S. squid exports to Italy.

U.S. salmon exports to Italy compete primarily with Canadian exports of frozen salmon. Canada has supplied over half of Italy's imports of salmon throughout the 1980's ($12 million out of $20 million in 1987, excluding canned). In 1987, competition increased when Norway became an important supplier of fresh salmon to Italy ($3.7 million). Norwegian exports of fresh farmed salmon to Italy will probably continue to increase, and may displace some of Italy's canned and frozen imports. Thus, although U.S. exports of frozen salmon to Italy recovered in 1988, Norway's increasing salmon exports may hinder further increases. Italian consumers strongly prefer fresh fish.

Other U.S. fishery exports to Italy have

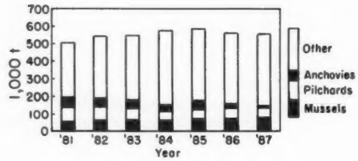


Figure 6.—U.S. imports of fishery products from Italy by commodity and value, 1981-88.

Table 8.—U.S. fishery exports to Italy, by commodity and quantity, 1981-88. U.S. Census Bureau data.

	Imports (metric tons)							
Commodity	1981	1982	1983	1984	1985	1986	1987	1988
Edible								
Fish								
Anchovies, canned	259	252	129	144	145	219	217	172
Tuna								
Fresh/frozen	2			227	347	465	261	13
Canned	18	3	5	9	7	15	18	18
(Tuna total)	(20)	(3)	(5)	(236)	(354)	(480)	(279)	(32)
Sardines, canned	74	24	23	81	257	75	95	30
Surimi						15		1
Salmon	Negl.[1]			Negl.	1	1	2	1
Shark fins							1	1
Other fish	11	33	15	21	72	108	64	84
Subtotal	354	282	172	482	829	898	658	320
Shellfish								
Shrimp, fresh/frozen			31	20	23	18	17	35
Clams								
Fresh/frozen			14	1	1	1	3	Negl.
Canned	5	17	48	74	52	12	7	9
(Clam total)	(5)	(17)	(62)	(75)	(53)	(13)	(10)	(9)
Crabs, fresh/frozen				3	3		2	3
Squid						1	1	Negl.
Other shellfish	13	9	13	22	11	3	22	Negl.
Subtotal	18	26	106	129	90	35	52	47
Other								
Antipastos			45	71	75	95	116	87
Soup preparations							14	5
Frogs							1	
Subtotal (edible)	382	308	323	682	994	1,028	841	459
Inedible								
Sponges	Negl.	1	1	2	8	3	28	4
Fish oils					1	1	1	Negl.
Shells	2	10	1	2	4		1	
Other inedible[2]	4	18	3	1	1	1	1	21
Subtotal (inedible)	6	30	5	5	14	5	31	26
Grand total	388	338	328	687	1,008	1,033	872	485

[1]Negl. = Quantity less than 1 metric ton.
[2]Primarily coral.

recently surged: Lobster exports multiplied from 1 t in 1987 to over 100 t worth $1.1 million in 1988; shrimp exports (both frozen and canned) increased from 6 t in 1987 to 40 t worth $0.24 million in 1988. Exports of mullet, cod, crabs, sea urchins, and clams, all negligible during most of the 1980's, increased appreciably in 1988, suggesting that the overall Italian market for U.S. fishery products is expanding.

An April 1988 report by the Irish Sea Fisheries Board identifies the following market opportunities for frozen fish in Italy: 1) Monkfish tails (1-4 pieces/kg), 2) shrimp, especially larger sizes (4-12 pieces/kg)[6].

U.S. Imports

U.S. imports of Italian fishery products increased to $3.0 million in 1985 (helped by the strength of the dollar), but decreased to $2.5 million in 1988 (Tables 7, 8; Fig. 6). Imports of canned fishery products, anchovies, sardines, and clams, have declined since 1987. Canned tuna imports have increased, but have not made up the loss in fresh and frozen tuna imports; the value of tuna imports decreased from over $1 million in 1986 to under $0.2 million in 1988. The only import which increased significantly in 1988 was shrimp, which doubled to $0.3 million. (Source: IFR-89/43.)

[6]About 2 to 6 pieces/pound.

The Coral Fishery and Trade of Japan

Japan harvested only 3 metric tons (t) of coral in 1988, down from 55 t in 1982. The decline in Japanese coral production has been due largely to a scarcity of new coral beds. Because of the destructive nature of coral fishing, coral beds are "mined out" in 4-5 years. Although domestic production has declined, the Japanese have imported an average of only 18 t of coral annually since 1983. Japan purchased nearly 18 t, valued at $4.4 million, in 1988.

Japanese coral fishermen are licensed by the Prefectural Governments of Tokyo, Kochi, Nagasaki, Kagoshima, and Okinawa, but are free from any national licensing system. In addition, there are no time, area, or vessel restrictions in force for coral fishing in Japanese waters. Because of this, no official Government records have been kept on the total amount of precious coral harvested in Japan.

There are three separate groups of coral fishermen in Japan: Coastal harvesters, submarine and robot harvesters, and the All Japan Coral Fisheries Association.

The coastal and shallow-sea coral fishermen operate out of Sukumo City, Kochi Prefecture. Although not officially organized, this group had about 100 small vessels ranging from 3 to 10 gross registered tons (GRT) in 1981. This number dropped to about 60 vessels in 1989. Each is usually manned by one fisherman for day-fishing off Tosa City, Kochi Prefecture (eastern Shikoku). The species of coral harvested (in the order of commercial value) are "red" or "oxblood" coral, *Corallium japonicum*, which is found at 200-300 m; "boke" or dark pink coral, *C. elatius*, which occurs at 250-400 m; "momo" or peach-pink coral, *C. nobile*, which is harvested at 150-300 m; and "shiro" or white coral, *C. konojo*, which is found at 100-200 m depths.

A small 2-man submarine and a robot operates out of Tokyo. They are owned by separate Japanese companies and have been harvesting coral since 1983 near the Amami Shoto Islands (lat. 28°N, long. 130°E). They harvest the same species as the Sukumo City coral fishermen.

Table 1.—Japan's coral harvest by fishing group, type of coral, and quantity, 1981-88, in kilograms.

	JCFA[1] harvest		Coastal harvest	Submarine robot	
Year	Midway deep sea	Red & pink	Red & pink	Red & pink	Total coral harvest
1981	30,484	0	4,084	0	34,588
1982	50,306	1,860	3,000	0	55,166
1983	49,312	1,775	2,947	153	54,187
1984	31,676	1,488	2,366	941	37,420
1985	7,890	1,432	2,366	1,065	12,753
1986	973	675	2,268	1,012	4,930
1987	0	585	1,968	423	2,976
1988	0	217	1,605	1,147	2,969

[1]All Japan Coral Fisheries Association.

Table 2.—Japanese coral imports by country and quantity, 1983-88, in metric tons.

	Coral imports (t)					
Country	1983	1984	1985	1986	1987	1988
Taiwan	9.8	0.5	12.6	23.0	26.2	13.3
France		1.4	1.0	0.6	1.3	1.5
Italy	0.4	0.2		0.2	0.4	0.5
Spain	0.9	3.8	0.8	0.2	0.1	0.4
Tunisia	2.3	1.4		0.3	0.1	0.2
Greece	0.1	0.3				
Others	2.5	Negl.[1]	0.5		0.1	1.8
Total[2]	16.0	7.4	14.9	24.3	28.3	17.7

[1]Negl. = Neglible.
[2]Columns may not sum to total due to rounding of numbers.

Table 3.—Japanese coral imports by country and value, 1983-88, in thousands of dollars.

	Coral imports ($1,000)					
Country	1983	1984	1985	1986	1987	1988
Taiwan	2,125	116	717	2,761	7,302	2,497
France		187	212	188	396	603
Italy	85	24		45	140	184
Spain	158	599	83	40	28	168
Tunisia	404	186		85	76	157
Greece	39	42				
Others	2	6	5		73	817
Total[1]	2,813	1,159	1,017	3,120	8,015	4,426

[1]Columns may not sum to total due to rounding of numbers.

The All Japan Coral Fisheries Association (JCFA) located in Kochi City, Kochi Prefecture, is comprised of "Midway Deep Sea Coral" fishermen. The "Midway Deep Sea Coral" is believed to be *Corallium* spp., and its color is light pink with darker spots. It has the lowest commercial value of all Japan's corals. The JCFA harvests the "Midway" coral in the area of about lat 36°N, long. 171°E, at depths of up to 1,000 m. The JCFA operated 17 vessels in 1981, each 100 GRT and with a crew of 10-15 fishermen.

Except for the coral bed located at the above coordinates, there have been no recent discoveries of new coral beds. The JCFA did not send any vessels to the "Midway" coral bed in 1987 and 1988, and only one vessel operated there in 1989. (A coral bed is reportedly fully exploited in 4-5 years.) Alternately, some Association vessels have been harvesting red and pink corals near the Bonin Islands off Tokyo. According to the JCFA, the depletion of the "Midway" coral beds may be the reason why Taiwan's coral fishing fleet in the same area decreased from 40 vessels (180-200 GRT) in 1965 to 35 vessels in 1988 and only 32 vessels in 1989.

The 100-GRT JCFA vessels harvest coral primarily by dredging. Dredges consist of concrete weights—about 20 kg each—with embedded rings attached to netting and hauling lines. These are towed over the coral beds breaking off and entangling coral pieces.

The JCFA estimates that the total Japanese harvest of precious corals has decreased from over 55,000 kg in 1982 to only 3,000 kg in 1988 (Table 1). Current average auction prices for corals are: Red coral, 2.5-3.0 million ¥/kg ($17,857-$21,428/kg); pink coral, 2.0 million ¥/kg ($14,285/kg); and Midway deep sea coral, 20,000 ¥/kg ($142/kg).

Despite the fact that Japan's harvest of coral has decreased, its annual imports of coral have averaged about 18 t since 1983 (Tables 2, 3). Japan imported 28 t in 1987, valued at over $8 million, up 77 percent by quantity and almost 200 percent by value over 1983 coral imports. Japan's 1988 coral imports, however, fell to 18 t, valued at $4.4 million—about half the value of the 1987 imports. Taiwan has historically been the major supplier of coral to the Japanese market, accounting for about 56 percent of the value of Japan's 1988 coral imports. France, Italy, Spain, and Tunisia also export coral to Japan. (Source: IFR-89/70, prepared by Paul E. Niemeier, Office of International Affairs, NMFS, NOAA, Department of Commerce, Silver Spring, MD 20910.)

Japanese Overseas Fisheries Aid Told

Japanese Government fisheries aid projects provide materials and technical assistance to promote economic and social development in, and maintain and enhance friendly relations with, recipient countries. In addition, Japan uses fisheries aid as a means of maintaining (or attaining) access to foreign waters for Japanese fishermen. For fiscal year 1989, Japan budgeted approximately $80 million for overseas fishery aid.

Background

Fisheries aid is only one category of economic development assistance within Japan's Overseas Development Assistance (ODA) program general budget account. (See Table 1 for a glossary of acronyms.) Although fisheries aid, like all ODA assistance, is administered by the Ministry of Foreign Affairs (MOFA), the Fisheries Agency of Japan (FAJ) plays a key role in the process. The FAJ effectively controls both fisheries aid policy and grants, because of its role in developing fisheries projects and its veto power over applications for fishery grants-in-aid.

To maximize benefits to its own people, the Japanese Government, usually provides fisheries assistance on a bilateral, year-by-year basis, rather than on a long term or multilateral development basis. In addition, the Government employs only Japanese consultants and contractors in administering aid projects.

Recent Aid Budgets

Japan's fisheries aid budget has steadily increased over the last 10 years (Fig. 1). In fiscal year 1989, the Japanese Government budgeted $3.2 billion for total foreign aid[1]. Of that amount, about $80 million was budgeted for fishery aid projects, nearly the same as the 1988 fishery aid budget of $79.4 million[2]. Japan's fisheries aid budgets for FY 1986 and 1987 were about $54 million and $67 million, respectively. In 1988, 52 percent of total fisheries aid went to Asian countries, 24 percent to Latin American countries, and 24 percent to African and Middle Eastern countries (Fig. 2). Some of Japan's biggest aid projects in 1988 were the $20 million Nakhon Si Thammarat port construction in Thailand, and the $8 million Puerto Deseado port extension in Argentina (Table 2).

Types of Projects

Fisheries Agency officials confirm that Government fisheries aid projects generally provide for such things as equipment necessary for fisheries development (fishing nets, small fishing boats, outboard motors, conventional freezing plants, icemaking equipment, refrigerated trucks, etc.), fishery training vessels, and the construction of fishery training/research facilities (laboratories, aquaculture facilities, and fishing ports). Because long-term regional development strategies do not adequately serve the fishing industry's need to respond quickly to changing resource availability and market conditions, Japanese Government fisheries aid projects typically provide help on a bilateral, year-by-year basis.

Administrative Procedures

Japanese Government grant assistance (including fisheries aid) is implemented by the Japan International Cooperation Agency (JICA). JICA provides the technical expertise for feasibility studies and planning of all aid projects.

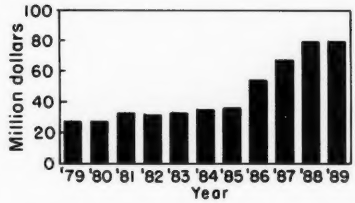


Figure 1.—Japan's overseas fisheries aid budgets by year, 1979-89, in millions of dollars.

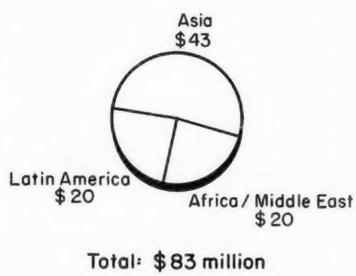


Figure 2.—Japan's 1988 fisheries aid grants by region and amount in millions of dollars.

Table 1.—Glossary of acronyms and role in Japanese overseas fisheries aid.

Acronym	Full name and role
FAJ	Fisheries Agency of Japan: Agency of the Japanese Government which handles all fisheries-related issues. Develops aid projects and has veto power over all grant applications.
JICA	Japan International Cooperation Agency: Implements all Japanese Government grant assistance; provides technical expertise in project feasibility studies and project planning.
MOFA	Ministry of Foreign Affairs: Ministry of the Japanese Government which handles foreign relations. Administers all overseas development assistance.
ODA	Overseas Development Assistance: General budgetary account of all Government aid grants to developing nations.
OFCF	Overseas Fisheries Cooperation Foundation: A private foundation closely linked to the FAJ which provides technical expertise in fisheries-related project planning. President is often a former FAJ official.

Table 2.—Japanese fisheries aid grants (in millions of dollars), by recipient country, amount, and project, 1988.

Country	Grant	Project/purchase
Thailand	$20.10	Nakhon Si Thammarat port construction
Argentina	$7.78	Puerto Deseado port extension
Columbia	$6.30	Coastal fishery development
Ecuador	$6.12	Construction of marine aquaculture center
Ghana	$6.07	Tema harbor rehabilitation
Mauritius	$5.40	Fishing port expansion
Western Samoa	$5.25	Apia port development
Marshall Isl.	$5.18	Majuro dock repair
Morocco	$4.49	Fishery development and outboard motors
Micronesia	$3.32	Bottom-fishing boat and tuna longliner
Palau	$2.64	Fishing community development
Benin	$2.36	Fisheries modernization
Tonga	$2.16	Shoreline protection
Fiji	$1.96	Fisheries promotion
South Yemen	$1.56	Training vessel repair
Bangladesh	$1.23	Fisheries development
Kiribati	$1.04	Fishermen training
Total	$82.96	

[1]Japan's fiscal year runs from April 1 to March 31 of the next year.

[2]Japan apparently exceeded this budget, and disbursed $82.96 million in fisheries aid in 1988 (appendix B).

According to FAJ officials, the FAJ is consulted and has veto power over all fisheries aid projects. This gives the FAJ effective control over fisheries aid, which is increasingly being used as a means to gain access to the Exclusive Economic Zones of recipient nations. The FAJ's ongoing relationship with those countries, in whose waters the Japanese fish, provides them with considerable opportunity to solicit applications and selectively approve fishery projects beneficial to Japanese interests.

JICA officials describe the procedures for obtaining Japanese Government fishery grants as follows:

1) MOFA and JICA must receive an official aid application from a foreign government (directly or through Japanese embassies abroad) before considering an aid request or beginning project planning.

2) The application is accepted by the Japanese Government.

3) A survey team is sent from JICA for preliminary project planning. The team usually includes FAJ, JICA, and Overseas Fisheries Cooperation Foundation (OFCF) staff and Japanese private consultants.

4) Consultations are then held between the Japanese Foreign Ministry, the Japanese Finance Ministry, and the foreign government involved.

5) Further Japanese Government interagency consultations are held.

6) There is a Japanese Government Cabinet decision and exchange of diplomatic notes.

7) Japanese contractors bid for the project, and a contract is signed with the successful bidder.

8) The contract is approved by the Foreign Ministry.

9) Japanese Government money is deposited in a Japanese foreign exchange bank with the account established under the name of the foreign government.

10) Finally, payment is made to the contractor in proportion to project completion.

Japan's Overseas Fisheries Cooperation Foundation (OFCF) is nominally a private foundation that contracts to assist in project development only after foreign countries have applied for aid assistance. Because of its extensive presence in the South Pacific and its close integral relationship with the FAJ, however, OFCF plays a key role in shaping both the Japanese Government's fisheries aid policy and the kinds of projects for which aid recipients apply. OFCF's funding comes from both fishing industry assessments and from the FAJ budget. OFCF's top management positions are usually held by former FAJ officials (OFCF's current president, for example, is former FAJ Director General Goroku Satake.) OFCF has a highly professional staff with field experience in distant water fisheries. (Source: IFR:89/53, prepared by Karen L. Kelsky and Paul E. Niemeier of Foreign Fisheries Analysis Branch (F/IA23), NMFS, NOAA, U.S. Department of Commerce, 1335 East West Highway, Silver Spring, MD 20910.

Salmon Culture in the Faroe Islands

The Faroe Islands, a group of 18 islands situated between Scotland and Iceland, is an ideal location for salmon culture. The islands are of volcanic origin, and Ice Age glaciers carved out deep valleys and narrow fjords where salmon can be raised undisturbed by human activities. The sea around the Faroes is influenced by the mixing of the warm Gulf Stream and the cold northern currents; this confluence generates large quantities of plankton and results in excellent feeding grounds for many species of fish. It also guarantees fairly stable ocean temperatures, between 5° and 10°C (40°-50°F) which produce healthy salmon. The basis of the Faroese economy is fishing, and fish farming is a welcome addition because the vegetation is sparse and only 6 percent of the land is cultivated. The economy is dependent upon fishery exports for nearly 97 percent of the nation's total foreign exchange earnings. In recent years, the catch of "traditional" species—cod, haddock, and whiting—has declined making fish farming a valuable source of future export earnings (every 10,000 metric tons (t) of exported farmed salmon yield nearly one quarter of the nation's gross national product).

Formative Years

Aquaculture began in the 1950's when a private individual began to breed rainbow trout. In 1973, the Faroese Government established a research station, P/f Fiskaaling, which took over the trout farming operations of the private firm, because of lagging production. P/f

Fiskaaling began experimenting with Atlantic salmon by raising smolts harvested from local rivers; the results were poor. In 1977, the research station obtained smolts from Iceland, but the results of these experiments were also poor. In 1978, P/f Fiskaaling biologists obatined smolts from Norway which grew quickly into healthy salmon. Most Faroese salmon originate from these Norwegian salmon smolts. In 1979, the first floating cages were installed in one of the many fjords that dot the shoreline. In 1982, when these pen-raised Atlantic salmon reached maturity, the first harvest of 60 t was reported. Progress in salmon farming was slow during the formative years, limited primarily by the lack of smolts.

Smolt Production

Despite the early experiments with Icelandic and Norwegian smolts, it was the policy of the Faroese Home-Rule Government to prohibit the importation of smolts (this policy is still in force) to prevent the exposure of local smolts to diseases; all smolts used for fish farming in the Faroe Islands in the early 1980's were delivered from the public-owned P/f Fiskaaling's three freshwater smolt farms, albeit from brood stock raised from the original smolts imported from Norway in 1978. Two private farms were allowed to produce smolts in 1983 and in 1984 a new socialist government adopted a policy aimed at encouraging small producers to operate both hatcheries and small-scale (7,500 to 10,000 m^3) fish farms. In 1984, the Government also established a raceway system and a smolt farm at Sundini (where it also grows sea trout). This action was especially important to help stimulate the growth of the Faroese salmon farming industry.

Government Support

The Faroese Home-Rule Government supported the start of the salmon farming industry by providing technical assistance and investment loans to fish farmers. These preferential loans provided by the Faroese Industrial Development Fund, were usually given for 10 years with a 2-year grace period, and covered up to 10 percent of the investment. Fish farms in the Faroes are privately owned, and the farmers operate them according to their individual wishes, using different methods and equipment. The Government, however, remains concerned about the effects of fish farming on the marine environment and strictly regulates salmon cage farming.

Farmed Salmon Production

The result of the efforts by private businessmen and the Home-Rule Government was a rapid expansion in the number of smolts available to local salmon farmers. By 1987, smolt production was estimated at 3 million and was expected to yield approximately 9,000 t of mature salmon by 1989. With a growing supply of healthy smolts, salmon harvests went from 470 t in 1985 to an estimated 4,800 t in 1987 (Table 1).

Fish Farm Board

In 1985, an 8-member Fish Farm Board was established, replacing an earlier 4-member committee formed in 1981. The new Fish Farm Board was given the following responsibilities: Reserve suitable areas for future fish farming, expand smolt production to keep pace with salmon farming, limit marine farming in areas vulnerable to environmental effects of fish farming, and produce a general plan for the use of limited freshwater resources. The Fish Farm Board was also made responsible for reviewing applications for new licenses and applications to expand existing facilities. Its responsibility includes salmon, rainbow/steelhead trout, and other species being raised in Faroese waters, including mussels.

Recent Developments

Despite the increase in production in 1986-87, unexpected problems have surfaced in several dramatic instances. In the summer of 1988, an algae bloom and reports of disease occurred in some fjords. In December 1988 and January 1989, storms raged through the Faroe Islands with winds recorded at 150 mph, causing immense damage to the islands and offshore fish cages. Many offshore farmers lost all of their fish and equipmenht to the storms, the worst in over 100 years. The recently elected conservative government responded by offering additional licenses and financial aid to fish farmers willing to develop offshore sites using large-capacity units. Prior to the storms, Faroese fishermen operated 17 offshore cages. Data on the number of cages damaged or destroyed by the storm were not available.

Salmon Exports

The Faroe Islands, a self-governing province of the Kingdom of Denmark, is not a member of the European Economic Community, even though Denmark is an EC Member State. This has restricted the Faroe's ability to market processed fishery products in the EC. Nevertheless, most of the Faroe's farmed salmon exports go to the Federal Republic of Germany, France, Denmark, the United Kingdom, Japan, and the United States. (Source: IFR-89/62.)

Table 1.—Faroe Islands salmon smolt hatcheries, production of salmon smolts, production of farmed salmon, number of salmon farms, and exports of salmon and trout, 1980-86, with projections for 1987-90.

	Salmon smolts		Farm-raised Atl. salmon		Export Salmon and trout	
Year	Hatcheries No.	Production (× 1,000)	Production (t[1])	Farms (No.)	Quantity (t)	Value (US$1,000)
1980	3	30		6	83	0
1981	3	40		6	101	0
1982	3	85	60	12	200	0
1983	5	169	105	22	410	NA
1984	5	345	116	30	550	NA
1985	5	1,255	470	50	1,350	623
1986	6	1,165	1,370	53	3,650	2,997
1987	NA	3,000	2,500 (E)	51	7,310	NA
1988	NA	NA	4,800 (E)	NA	NA	NA
1989	NA	NA	7,000 (E)	65	NA	NA
1990	NA	NA	9,000 (E)	NA	NA	NA

[1]Live weight; may invlude farmed trout. E = estimate.

Japan's Sea Cucumber Harvest and Market

Japan purchased 78 metric tons (t), valued at about $1.4 million, of sea cucumber or beche-de-mer commodities in 1988 and lands about 7,100 t (Table 1). The United States, the second largest supplier to Japan's sea cucumber market, exported 22 t, valued at about $285,000 (Tables 2, 3). Japan's major source of sea cucumbers is Korea (28 t, worth $890,000).

Consumption

Fresh sea cucumber, known as "namako," is consumed cured with vinegar in Japan. Boiled and dried sea cucumber or "iriko" is an essential ingredient for Chinese cuisine. Fermented viscera of sea cucumber, known as "konowata," is considered a delicacy in Japan. Although the consumption of fresh sea cucumber at the Tsukiji Fish Market in Tokyo appears to be stable at about 700-800 t per year, dried sea cucumber for the Chinese food market is said to have decreased drastically in the recent years. According to a major Chinese food wholesaler in Tokyo, the firm's sales of dried sea cucumber decreased two-thirds in 5 years to about 3 t a year. The decrease has been attributed to the unattractive appearance of live sea cucumbers to Japan's younger generations.

Table 1.—Japan's total sea cucumber landings by quantity (t) and price (¥/kg), 1976-87.

Year	Quant.	Price	Year	Quant.	Price
1976	10,579	479	1982	8,437	618
1977	9,793	444	1983	8,295	648
1978	10,143	441	1984	7,624	692
1979	9,381	551	1985	7,862	670
1980	8,970	569	1986	7,248	676
1981	8,098	630	1987	7,132	N/A[1]

[1]N/A = Not available.

Species

Common Japanese sea cucumber species are "manamako," *Stichopus japonicus*; "baika-namako," *Thelenota ananas*; "oki-namako," *Parastichopus nigripunctatus*, and "kinko," *Cucumaria frondosa japonica*. "Ma-namako" is the most common species and is found in shallow waters surrounding Japan. It grows up to 30 m long and 8 cm wide. "Ma-namako" is excellent for raw consumption, as well as for "iriko" and "konowata". Baika-namako" is Japan's largest sea cucumber species, reaching lengths of 70-80 cm. It is found in waters from Okinawa to Micronesia. "Iriko" made from "baika-namako" is considered a high-valued product and is known as "gajimaru" in Okinawa and "haishen" in China. "Oki-namako" is found in the western coastal waters of Japan in depths up to 160 m. It grows to 40 cm and is good for "iriko." "Kinko" is oval shaped and is found along the coast of the Sea of Japan and north of Ibaragi Prefecture (northeastern Honshu) to Hokkaido. Japan's total annual production of sea cucumber is about 7,100 t, most of which is "ma-namako" (Table 1).

Marketing

Fresh

All species are treated equally in the fresh market, but color, size, and origin are important. According to one specialist at a Tsukiji Central Wholesale Market (TCWM) auction house in Tokyo, brown or green-colored live sea cucumbers in the 200-500 g range are the most acceptable for fresh consumption. Large sea cucumbers and sea cucumbers found in warm waters are said to be too tough to eat. Fresh or live Japanese sea

Table 2.—Japanese frozen sea cucumber imports by month, country, quantity, and average price[1], 1988.

	Imports									
	Korea		Canada		United States		China		Fiji	
Month	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg
Jan.			1,000	534						
Feb.			1,080	1,402						
Mar.	90	3,867	9,040	1,263						
Apr.	1,964	1,480			543	618				
May	1,445	1,594			1,020	2,063				
June	5,618	1,402	6,000	1,108	2,000	1,977	169	7,485		
July	711	6,752			4,950	1,829				
Aug.					6,830	1,887				
Sept.										
Oct.									6,128	682
Nov.					1,556	1,872				
Dec.	250	6,998			3,559	3,700				
Total	10,078	1,983	17,120	1,175	20,458	1,604	169	7,485	6,128	682

[1]Prices are quoted CIF.

Table 3.—Japanese imports of dried, salted, or brined sea cucumber by month, country, quantity, and average price[1], 1988.

	Imports									
	Korea		Canada		United States		Singapore		Maldives	
Month	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg
Jan.	224	3,085			88	2,386				
Feb.	348	4,026			443	1,926				
Mar.	1,013	4,247					212	1,037		
Apr.	2,387	4,809							250	2,212
May	3,848	7,981								
June	3,905	5,850			365	1,432	1,000	1,041	2,000	2,027
July	1,633	5,933								
Aug.	627	5,282	175	8,011						
Sept.	1,220	5,373								
Oct.					907	2,002				
Nov.	792	5,784								
Dec.	2,213	8,559	140	2,922						
Total	18,210	5,159	315	5,749	1,803	1,887	1,212	1,040	2,250	2,047

[1]Prices are quoted CIF.

cucumbers are usually sold for 500-1,500 ¥/kg (Table 4). The price depends on the supply and is the highest from August to November. Fresh sea cucumbers are packed in 10 kg (net) flat cartons with 3 blue-ice packs per carton. After depuration in holding tanks, over 12 kg of sea cucumbers are packed to meet the net weight of about 10 kg upon arrival at market. About 20 percent of the original weight is lost during shipment through water loss. Specialists do not recommend freezing fresh sea cucumbers because they reportedly disintegrate when thawed.

Dried

Dried sea cucumber is produced by repeated boiling and drying. The Japanese market for dried sea cucumber seems to be limited because the dried product is used only by Chinese restaurants. However, the potential market for imported dried sea cucumber may be around 50 t a year, according to a Tokyo wholesaler specializing in Chinese food. Dried sea cucumber (10 percent moisture content) for the Japanese market is sorted to 1) no more than 30 pieces/600 g and 2) 31-70 pieces/600 g. One carton contains 20 kg and 2 cartons comprise a 40 kg master carton. Some Carlifornia exporters, however, use gunny sacks. Dried sea cucumbers are usually distributed by wholesalers specializing in Chinese foods. The wholesale price is about 13,000-23,000 ¥/kg, depending on quality. The quality of dried sea cucumbers is judged by the state of the cucumber after reconstitution with water. The texture of the sea cucumber's gelatinous meat must be like pudding and the reconstituted weight should be 4-5 times the dry weight. Sea cucumbers harvested off San Francisco and Los Angeles are of good quality and most are exported to Taiwan. The Japanese claim that Alaskan sea cucumber, however, is of inferior quality with little meat. Some dressed sea cucumbers, which are frozen in nitrogen after reconstitution from the dried state, are imported to Japan. However, thawing this type of frozen sea cucumber is reportedly difficult. No published statistics on dried sea cucumbers are available.

According to *INFOFISH* magazine, Hong Kong is the largest distribution center for dried sea cucumber in Asia. Japan also exports dried sea cucumber to Taiwan and Hong Kong. Taiwan imports high quality products only, whereas Hong Kong imports all grades and re-exports low quality products to China.

Fermented

"Konowata" is considered a delicacy in Japan. It is eaten mainly when drinking sake or whiskey. About 8-10 t are sold at TCWM per year. Wholesale prices at TCWM are about 4,000-8,000 ¥/kg (Table 5). It is difficult to determine the current total market size for "konowata" in Japan. The publication "Marine products in Japan by E. Tanikawa (cited at the end of this report) describes the production process in detail: Sea cucumber viscera (alimentary canal and reproductive organs) are first thoroughly cleaned. Salt, equivalent to 10-15 percent of the total wet weight of the visceral mass, is then added. The mixture is stirred frequently for about 5 hours, drained, and then put in barrels for about a week to age. The "konowata" is packaged for restaurants in 1 kg units in flat wooden barrels, or for retail in small glass jars or wooden barrels containing about 100 g. The retail price of a glass jar containing about 100-120 g is about ¥3,000 each. Regular supermarket or department stores do not usually carry "konowata." It is only found at specialty stores. (Source: IFR-89/69R, prepared Paul E. Niemeier, Office of International Affairs, NMFS, NOAA, Department of Commerce, Silver Spring, Maryland 20910.) Publications which describe the sea cucumber drying process include:

Tanikawa, E. "Marine products in Japan," Koseisha-Koseikaku Company, 8 Sanei-cho, Shinjuku-ku, Tokyo.

Sachithananthan, K. 1986. "Artisanal handling and processing of sea cucumbers (sand fish)." *INFOFISH Digest*, No. 2/86:35-36.

Nearshore Magazine. 1987. "Preparing beche-de-mer for export." Fisheries, Inc., P.O. Box 783, Wakefield, Rhode Island 02882. June:13-15.

Table 4.—Fresh or live sea cucumber at Tokyo's Tsukiji Central Wholesale Market (TCWM) by month, quantity, and average price, 1984-87.

	Sales							
	1984		1985		1986		1987	
Month	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg
Jan.	136,493	650	147,826	564	143,224	677	138,305	648
Feb.	102,017	847	111,584	613	130,112	602	124,983	550
Mar.	105,373	739	109,714	520	132,483	512	117,600	491
Apr.	46,874	779	46,218	524	52,771	495	43,164	487
May	25,457	496	19,575	611	19,456	623	21,251	603
June	14,600	498	14,521	639	13,349	543	10,447	698
July	12,088	501	12,055	651	13,725	665	10,618	767
Aug.	7,105	599	7,298	623	7,000	761	4,577	1,165
Sept.	11,146	834	7,271	999	7,171	1,071	6,399	1,567
Oct.	20,257	1,455	12,307	1,619	16,752	1,525	12,235	1,839
Nov.	95,061	848	64,119	1,373	65,517	1,124	55,082	1,245
Dec.	196,265	791	173,579	941	182,499	878	180,290	994
Total	772,736	769	726,067	804	784,064	727	704,951	753

Table 5.—Japanese fermented sea cucumber (konowata) sales at TCWM by month, quantity, and average price, 1984-87.

	Sales							
	1984		1985		1986		1987	
Month	kg	¥/kg	kg	¥/kg	kg	¥/kg	kg	¥/kg
Jan.	2,130	8,254	1,922	8,368	1,300	8,065	1,272	7,889
Feb.	2,068	6,445	1,575	6,126	1,473	8,882	1,308	10,180
Mar.	1,386	6,862	1,155	5,875	1,996	8,134	1,160	8,338
Apr.	291	7,136	1,027	5,618	999	5,167	487	6,917
May	381	5,695	215	5,200	376	4,983	494	5,170
June	227	7,548	411	4,529	486	4,506	780	4,154
July	392	6,134	400	3,663	214	4,004	270	4,917
Aug.	337	7,277	261	6,454	313	5,453	293	4,391
Sept.	208	6,731	225	5,299	391	4,994	349	6,511
Oct.	374	6,444	834	5,922	429	5,611	438	5,979
Nov.	475	7,271	555	4,751	646	5,249	371	5,537
Dec.	1,027	6,390	1,661	5,588	1,228	3,301	822	8,375
Total	9,296	6,999	10,241	6,099	9,851	6,435	8,044	7,289

Japan's Sablefish Supply and Market

The current Japanese demand for sablefish, *Anoplopoma fimbria* (also known as black cod), is estimated to be around 30,000 metric tons (t) per year, and is growing steadily. It is supplied almost entirely by imports. Japan's 1988 sablefish imports totaled 30,500 t, valued at about $158 million, an increase of 7 percent by quantity and 33 percent by value over 1987 imports (Table 1).

The United States is the primary supplier, shipping about 90 percent (27,200 t valued at $140 million) of the 1988 total. Canada, Mexico, Morocco, and the Republic of Korea also supplied small amounts. Japan's purchases of sablefish have increased by over 450 percent since 1983, when the United States began to cut Japanese sablefish catch allocations within the U.S. Exclusive Economic Zone (EEZ). The outlook for 1989 U.S. sablefish exports to Japan is favorable. During the first 6 months of 1989, the United States shipped nearly 16,000 t, valued at $72 million—up 7 percent by quantity but down 10 percent by value, over 1987 imports of 15,000 t, worth $80 million. The lower value may be a result of market oversupply.

Consumption

Sablefish is a popular and relatively inexpensive fish that is primarily consumed during the winter months in northeastern Japan, especially in Tokyo and Kanagawa Prefectures. The southwestern part of Japan is also a potential market. Sablefish competes with species such as rockfish and turbot, which have similar seasons and prices, and it is sometimes substituted for salmon when salmon prices are high.

Supply

Nearly the entire U.S. and Canadian sablefish catch is used to supply the Japanese market. The combined catch of the two countries totaled 52,500 t in 1988 (Table 2), with the United States accounting for 48,000 t (91 percent) and Canada 4,500 t (9 percent. The dressed weight[1] of the combined catch was approximately 34,000 tons. The value of the 1988 U.S. sablefish catch was about $92 million. Cold storage holdings in the United States and Canada at the end of 1988 reportedly totaled only 1,000-1,500 tons.

The U.S. sablefish catch has more than doubled since 1984. U.S. domestic annual harvest (DAH) allocations within the EEZ have inceased steadily since the early 1980's, reflecting the increased growth and efficiency of the U.S. sablefish industry. The United States, however, cut the 1989 DAH by about 5 percent because of concern over potential sablefish stock depletion in the Bering Sea, Aleutian Islands, and Gulf of Alaska. Within the Bering Sea, the sablefish allocation was reduced to such an extent that directed fishing was prohibited, and the quota of 2,380 t was to caught only as a by-catch. In the Gulf of Alaska, the Secretary of Commerce implemented a total allowable catch of 26,000 t for 1989, of which 3,600 t was assigned as by-catch for trawlers in other directed groundfish fisheries. The remainder of the quota was for the sablefish hook-and-line fishery. There was no directed trawl fishery for sablefish in the Gulf of Alaska in 1989. As a result of these actions, the 1989 sablefish supply was expected to decrease.

Prices

The dramatic fall of the U.S. dollar

[1]The preferred sablefish product form is headed and gutted. The conversion rate from round weight to headed and gutted weight is about 65 percent.

Table 1.—Japanese imports[1] of frozen sablefish by country, quantity (t), and value ($1,000), 1987-89.

	1987		1988		Jan-June 1989	
Country	Quantity	Value	Quantity	Value	Quantity	Value
U.S.A.	25,770	105,215	27,186	139,610	15,997	72,053
Canada	2,765	13,007	3,162	17,758	1,093	5,294
Mexico			188	551		
Morocco			17	17		
Korea, N.					18	61
Korea, S.	21	75	4	24	10	35
Hong Kong	28	67				
Total	28,584	118,364	30,557	157,980	17,118	77,443

[1]Note: Japan did not begin to report separate import statistics for sablefish until 1987. Prior to that time, sable fish import statistics were lumped together with those of cod and cod-related species.

Table 2.—U.S. and Canadian sablefish catches by year, 1984-89[1].

	U.S. catch (t)		Canadian catch (t)		Total catch (t)	
Year	Round wt.	Dress[2]	Round wt.	Dressed[2]	Round wt.	Dressed[2]
1984	22,720	14,768	3,852	2,503	26,572	17,272
1985	28,843	18,748	4,282	2,783	33,125	21,531
1986	38,930	25,305	4,500	2,990	43,530	28,295
1987	46,707	30,360	3,726	2,422	50,433	32,782
1988	47,996	31,197	4,517	2,933	52,513	34,130
1989[1]	41,670	27,086	4,015	2,610	45,685	29,696

[1]1989 U.S. and Canada domestic catch allocations.
[2]Estimated using a conversion rate of 65 percent.

against the yen in recent years has made U.S. sablefish very attractive to Japanese buyers. Consequently, they have imported large quantities at relatively low prices. Tokyo Central Wholesale Market prices for frozen sablefish at the end of August 1989 were \$2.67-2.73/lb. for 5-7 and 7-plus lb. fish, \$2.42-2.48/lb. for 4-5 lb. fish, \$2.13-2.24/lb. for 3-4 lb. fish, and \$2.00-2.03/lb. for 2-3 lb. fish. These prices were \$0.25 to \$0.45 below prices for the same period in 1988. The reasons for the lower market prices were not well understood, but may have been a result of oversupply. Japanese sablefish market prices generally depend on the results of the spring and fall fishing seasons off Alaska. Prices usually peak in April, when Japanese inventories are lowest, and fall substantially during the fall chum salmon season. According to the *Suisan Keizai Shimbun*, a Japanese fishing industry paper, 1988 imports were controlled by a few leading importers who supported the market to prevent prices from falling to the low levels of 1986 and 1987. Because of the market's dependence on imports, there was concern that further fluctuation in the yen/dollar exchange rate would continue to adversely affect sablefish prices in 1989.

Outlook

The condition of sablefish stocks was in question in mid 1989. Although the results of the 1988 Japanese-United States cooperative longline survey indicated that the sablefish biomass remained stable, the condition of the 1984 year class was uncertain. (Sablefish enter the commercial fishery when they are 4-5 years old.) Consequently, beginning in 1989 overall supply was expected to decline slightly, with higher prices. As the catch ceiling necessary to ensure sablefish stock preservation is not likely to exceed 50,000 t in the near future, the growth potential of Japan's sablefish market is limited. (Source: IFR-89/90, prepared by Paul E. Niemeier, Foreign Fisheries Analysis Branch (F/IA23), NMFS, NOAA Department of Commerce, Silver Spring, Maryland 20910.)

Iceland's 1988 Fish Catch Sets Record

Iceland's fisheries catch reached a record 1.7 million metric tons (t) worth \$315 million in 1988, vs. 1.6 million t worth \$287 million in 1987. Cod again proved slightly less plentiful in 1988 (376,000 t vs. 390,000 t in 1987), but this was offset by the increase in the value of these landings; \$315 million vs. \$289 million in 1987. The catch of all other finfish, however, increased both by quantity and value in 1988. The capelin catch (used mostly for reduction), reached 909,200 t in 1988 (vs. 803,000 t in 1987), helping to increase the overall catch. The shellfish harvest, however, declined in both quantity and value when compared with 1987. The shrimp harvest declined from 38,600 t worth \$79 million to 29,700 t worth \$73 million. The drop in the catch of high-value species (cod, Norway lobster, shrimp, and scallops) together with lower demand in the United States market, produced some problems in the fish processing sector.

The Government of Iceland imposed both a quota and an export tax in an attempt to keep fresh fish available to processors, but despite this action, exports of fresh fish increased by over 22 percent in 1988. The U.S. market declined to 15 percent of the value of total fishery exports in 1988 (38,100 t worth \$167 million), while the continued growth in Icelandic sales to the United Kingdom have made it Iceland's most important market. Reductions in Iceland's cod quotas from 315,000 t in 1988 to 285,000 t in 1989, and uncertainty about shellfish stocks suggest that 1989 would be a poorer year for Icelandic fishermen and the Icelandic economy which depends on fishery exports for over three-fourths of its total export earnings. The small fish farming sector, however, remains a bright spot. Farmed salmon harvests were 900 t in 1988 and was projected to be 4,000 t in 1989 and more than 15,000 t in 1990.

The U.S. Embassy in Reykjavik has prepared a 13-page report reviewing Icelandic fisheries during 1988. The report includes sections on Iceland's fisheries catch, fish processing, overseas marketing, fish farming, and the 1989 outlook. The report also includes statistical tables on Iceland's fisheries catch and how it is utilized, exports of fishery products by destination, exports by product form, exports to the United States, and Iceland's fishing fleet and number of fishermen. U.S. companies can obtain a copy of "Icelandic Fisheries, 1988" for \$13.95 and a \$3.00 handling fee (total of \$16.95, personal checks or money orders only) by ordering report PB89-197230/GBA from NTIS, 5285 Port Royal Road, Springfield, Virginia 22161. (The handling fee is per order, regardless of how may reports are ordered.) (Source: IFR-89/72N.)

Giant Tiger Prawns and Their Culture

Publication of "**Biology and Culture of *Penaeus monodon***" by the BRAIS Project Staff has been announced by the Brackishwater Aquaculture Information System, Southeast Asian Fisheries Development Center, Tigbauan, Iloilo, Philippines. The volume, authored by members of the BRAIS Project Staff and second in the BRAIS State-of-the-Art Series of publications, is a thorough review of the biology, ecology, and culture of the giant tiger prawn or "sugpo."

Much work on the species, important in aquaculture in the Indo-Pacific region, has been done by the SEAFDEC Aquaculture Department, and each chapter of the publication consolidates and synthesizes recent data in the respective fields. Following chapter one, which reviews the species' taxomony, morphology, distribution, bionomics, and life history, various authorities cover: Maturation, reproduction, and broodstock technology; hatchery operations and management; prawn grow-out practices in the Philippines; nutrition; and diseases. Each chapter presents selected references for further information. Paperbound, the 178-page handbook costs US$50 (P300), and is available from Sales/Circulation, Publications Section, Information Division, SEAFDEC, AQD, P.O. Box 256, Iloilo City, Philippines.

Also available from SEAFDEC is the "**Directory of Brackishwater Aquaculture Scientists,**" an 82-page paperbound listing of 202 researchers, arranged alphabetically, who are involved in this aspect of fish culture. Given are the scientists' names, affiliations and addresses, degrees earned, field of specialization, and the species that they are knowledgeable about. It costs US$25 (P100). Another BRAIS item is the "Directory of Brackishwater Aquaculture Institutions," an 89-page listing that costs US$30 (P150).

In September 1987, a Seminar on Aquaculture Development in Southeast Asia was held in Iloilo City, Philippines. The proceedings of tha have also been published by SEAFDEC as "**Perspectives in Aquaculture Development in Southeast Asia and Japan,**" which is subtitles Contributions of the SEAFDEC Aquaculture Department. The proceedings, a comprehensive account of the seminar, reviews and examines the existing aquaculture technologies in Southeast Asia, evaluates the contribution of SEAFDEC's Aquaculture Department to these technologies, and suggests future avenues of regional aquaculture research and training.

Articles provide, first, a broad overview of the region's aquaculture industry, and then more specific analyses of aquaculture development in Japan, Malaysia, the Philippines, Singapore, Thailand. Other contributions discuss broodstock management and seed production of *Penaeus monodon*; milkfish; rabbitfish, *Siganus guttatus*; sea bass, *Lates calcarifer*; tilapia; carp; and the farming of mussels and oysters. A final chapter review the training programs of the SEAFDEC Aquaculture Department. The 316-page paperbound volume is available from SEAFDEC (price not listed).

Other SEAFDEC publications produced include extension manuals ("Nutrition and feeding of *Penaeus monodon,*" US$28, P80; "Broodstock of Sugpo," US$28, P80) as well as extension pamphlets and color posters on prawns and prawn culture.

Assessment of Fish Diseases

"**Methods for the Microbiological Examination of Fish and Shellfish,**" edited by B. Austin and D. A. Austin who are with the Heriot-Watt University's Department of Biological Sciences, Edinburgh, Scotland, has been published by John Wiley & Sons, Inc., 605 Third Avenue, New York, NY 10158 in the Ellis Horwood Series in Aquaculture and Fisheries Support. Disease remains an important problem and an impediment to aquaculture although many advancements have been made in recent years. This new multi-authored volume is a manual for those with not only an interest in fish diseases, but who are directly involved in the practical, day-to-day aspects of fish disease and diagnostics. And the many authors have provided detailed and practical information here on the methods used for the study of fish and shellfish microbiology.

Following a general introduction, chapters discuss methods for sampling fish and shellfish, live and dead; transportation of samples, clinical examination of diseased fishes and shellfishes, histology, serology, microflora of healthy animals, various bacterial pathogens of aquatic vertebrates, the isolation and characterization of fungal and viral pathogens/parasites, and human pathogens in shellfish.

Material is included on disease signs indicated by observation of infected stocks, behavioral changes that are attributable to diseases in fish, external appearances and internal clinical signs indicative of diseases, and more. The chapters conclude with bibliographical or selected references for further guidance. In short, this is a good, practical guide to fish and shellfish problems and how to assess them. Included are organism and general indexes, and the 317-page hardbound volume is available from the publisher at $89.95.

What Is a Gadiform?

"Papers on the Systematics of Gadiform Fishes," edited by Daniel M. Cohen, has been published by the Natural History Museum of Los Angeles County, 900 Exposition Blvd., Los Angeles, CA 90007, as number 32 in its Science Series. The book is an outgrowth of the Workshop on Gadiform Systematics (WOGADS) which was convened at the Museum in January 1986. The meeting addressed three basic points: 1) What belongs in the Gadiforms? 2) What is the relationship of the order to other groups? and 3) What are the interrelationships among gadiforms? The presentations in this volume, then, are an effort to answer those basic questions—obviously not an easy task.

Two papers are presented by Dirk Nolf and Etienne Steurbaut, one in which they characterize most gadiform fishes by a unique otolith character, noting similarities between otoliths of gadiforms and batrachoids and suggesting ophidiiforms as a possible sister group. In the other paper they describe and compare the otolith-based fossil record for gadiforms and ophidiiforms and discuss hypotheses on the evolution and paleoecology of them. Douglas F. Markle, in "Aspects of character homology and phylogeny of the Gadiforms," considers the gadiforms to be monophyletic, as do Colin Patterson and Donn E. Rosen who evaluate the characters and relationship of gadiform fishes within the framework of the Paracanthopterygii, accepting the consensus, including in the Gadiformes the macrouroids and excluding ophidioids and zoarcids. Markle also excludes ophidiiforms and zoarceoids, and calls the batrachoids the most likely sister group.

Additional papers then deal at length with the various taxa within the gadiforms, with various authors utilizing different character sets, different evaluations of the meaning of character states, and different analytic methodologies to arrive at considerably different conclusions. As editor Cohen notes, this ". . . makes it abundantly clear that gadiform systematics remain far from a closed book." This book, however, does a fine job of elucidating the differences in approaches to gadiform systematics and the varied conclusions for the systematics student. Hardbound and indexed, the 262-page volume is available from the publisher at $50.00.

Canada's Response to the LOS Regime

Publication of **"Canadian Oceans Policy, National Strategies and the New Law of the Sea"**, edited by Donald McRae and Gordon Munro, has been announced by the University of British Columbia Press, 6344 Memorial Road, Vancouver, BC Canada V6T 1W5. McRae is Dean, Common Law Section, Faculty of Law, University of Ottawa and Munro is professor of economics, University of British Columbia.

This volume presents a multidisciplinary perspective on the nature and adequacy of Canada's ocean management policies and practices in light of the international regime that emerged from the 1982 Convention on the Law of the Sea. Chapter authors are noted lawyers, political scientists, economists, fisheries scientists, and diplomats who specialize in various marine disciplines.

The first two chapters specifically address fisheries matters and illustrate the wide range of issues that Canada has had to confront in implementing its 200-mile zone, particularly in relation to the allocation of shares of resources to foreign fishing vessels. Parzival Copes first reviews the international dimensions of Canadian fisheries management policy, and notes that long-term economic prospects for distant-water foreign fleets in the Canadian zone do not appear bright; this may help ease some of Canada's marine fishery management problems. Munroe and Robert L. Stokes then review the Canada-United States Pacific salmon treaty, providing a historical background to it and assessing the important legal, biological, political, and economic aspects of it, but stressing the economic aspects.

Part 2 considers Canada's seabed mineral resources, while Part 3 treats the marine environment and its protection, and Canadian policy on aquatic science research, in which Norman J. Wilimovsky states: "Management of natural resources is heavily dependent on basic and applied research. Identification of research needs and their relative priorities in the context of regional or naional policy requires documentation for rational evaluation. Policy formulation begins at the top, but to be realistic and workable, such policies require development upward and from the local or regional level."

Chapters on sovereignty discuss the delimitation of maritime boundaries, sovereignty and security in the Arctic, and the balance between seapower, security, and sovereignty. Final chapters assess the future of international oceans management and both domestic and international dimensions of future Canadian oceans policy. The 268-page volume is available from the publisher at $39.95 (hardbound) and $22.95 (paper).

New NMFS Scientific Reports Published

Some publications listed below may be sold by the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. Copies of all are sold by the National Technical Information Service, Springfield, VA 22151. Writing to either agency prior to ordering is advisable to determine availability and price (prices may change and prepayment is required.)

NOAA Technical Report NMFS 67. Squires, Dale. **"Index numbers and productivity measurement in multispecies fisheries: An application to the Pacific coast trawl fleet."** July 1988, iii + 34 p., 1 fig., 36 tables, 6 app.

ABSTRACT

This study is concerned with the measurement of total factor productivity in the marine fishing industries in general and in the Pacific coast trawl fishery in particular. The study is divided into two parts. Part I contains suitable empirical and introductory theoretical material for the examination of productivity in the Pacific coast trawl fleet. It is self-contained, and contains the basic formulae, empirical results, and discussion. Because the

economic theory of index numbers and productivity is constantly evolving and is widely scattered throughout the economics literature, Part II draws together the theoretical literature into one place to allow ready access for readers interested in more details.

The major methodological focus of the study is upon the type of economic index number that is most appropriate for use by economists with the National Marine Fisheries Service. This study recommends that the following types of economic index numbers be used: chain rather than fixed base; bilateral rather than multilateral; one of the class of superlative indices, such as the Tornqvist or Fisher Ideal.

NOAA Technical Report NMFS 68. McHugh, J. L., and Marjorie W. Sumner. **"Annotated bibliography II of the hard clam *Mercenaria mercenaria*."** September 1988, iii + 59 p.

SUMMARY

This publication we add another 460 citations to an earlier collection of 2,233 titles (McHugh et al., 1982), nearly all accompanied by abstracts. This bibliography is divided into three parts. Part 1 comprises the bulk of the bibliography, while parts 2 and 3 contain additional titles that we decided to include during editing, submission, and approval of the manuscript for publication. All three parts are indexed together, however. Reexamined were those titles in the previous bibliography (McHugh et al., 1982) which did not include abstracts. These are included in Parts 2 and 3 of this bibliography.

NOAA Technical Report NMFS 69. Sindermann, Carl J. (editor). **"Environmental quality and aquaculture systems. Proceedings of the thirteenth U.S.-Japan meeting on aquaculture, Mie, Japan, October 24-25, 1984."** October 1988, iii + 50 p.

CONTENTS

Relationship between fish culture methods and pondwater quality in freshwater fish culture by C. Kenji; Environmental management of larval rearing of marine fishes—A short history of research to prevent lordosis in red sea bream, *Pagrus major* by K. Fukusho and C. Kitajima; Salinity tolerances of marine bivalves by S. Funakoshi, T. Suzuki, and K. Wada; Temperature preference of immature horse mackerel, *Trachurus japonicus*, in a vertical temperature gradient by A. Furukawa, H. Fukatani, and S. Tsuchida; Effects of environment on seedlings of king crab, *Paralithodes camtschaticus* by T. Nakanishi; Some methods of water-flow control for mariculture by T. Noma; and Environmental conditions in pearl oyster culture grounds in Japan by K. Ohwada and H. Uemoto.

NOAA Technical Report NMFS 70. Sparks, Albert K. (editor). **"New and innovative advances in biology/engineering with potential for use in aquaculture. Proceedings of the fourteenth U.S.-Japan meeting on aquaculture, Woods Hole, Massachusetts October 16-17, 1985."** November 1988, iii + 69 p.

CONTENTS

Chum salmon growth hormone: isolation and effects on growth of juvenile rainbow trout by H. Kawauchi and S. Moriyama; Cloning and expression of cDNA for salmon growth hormone in *Escherichia coli* by S. Itoh, S. Sekine, and H. Kawauchi; Molecular toxicology: A new frontier by T. T. Chen, R. J. VanBeneden, L. B. Agellon, D. A. Howard, and R. A. Sonstegard; Necessity of dietary sterols and phospholipids for growth of the prawn, *Penaeus japonicus* Bate by S. Teshima and A. Kanazawa; Applications of endocrinology to salmon culture: Hormonal induction of spawning of adults and hormone patterns during development of juveniles by W. W. Dickhoff; Isolation and development of protoplast in *Porphyra* by H. Kito; Genetic engineering and biotechnology of economically important seaweeds by D. P. Cheney; Mass culture of *Ulvella lens* as a feed for abalone, *Haliotis discus hannai* by K. Takahashi and A. Koganezawa; Bacterial products and polysaccharide films as cues and enhancers of oyster set by R. M. Weiner, L. Dagasan, M. P. Labare, R. R. Colwell, D. B. Bonar, and S. L. Coon; Juvenile hormone in crustacea by H. Laufer, D. Borst, F. C. Baker, and D. A. Schooley; Recent advances in nursery culture of bivalve mollusks in North America by J. J. Manzi and N. H. Hadley; Tissue culture and genetic engineering for seaweed aquaculture by N. Saga and Y. Sanbonsuga; Preliminary investigations on cryopreservation of marine bivalve gametes and larvae by L. L. Ellis; Microparticulate diets for fish larvae by A. Kanazawa and S. Teshima; Sowing culture of scallop in Japan by H. Ito.

NOAA Technical Report NMFS 71. Alton, Miles S., Richard G. Bakkala, Gary E. Walters, and Peter T. Munro. **"Greenland turbot *Reinhardtius hippoglossoides* of the eastern Bering Sea and Aleutian Islands region."** December 1988, iii + 31 p., 34 figs., 10 tables.

ABSTRACT

Greenland turbot (*Reinhardtius hippoglossoides*) is a commercially important flounder in both the North Atlantic and North Pacific Oceans. In the latter, its center of abundance is in the eastern Bering Sea and along the Aleutian Islands chain where its population is managed as a single stock. Harvest levels in this region of the North Pacific during the period 1970-81 were comparable with those in the northwest and northeast Atlantic, with annual average catches of 53,000 metric tons (t). However, the catch in 1984 dropped sharply to 23,100 t, in part because of reduced quotas arising from concern over continued poor recruitment and declining catch-per-unit-effort.

Recruitment failure was manifested in 1) the sharp decline in the catch rate of young fish in annual research trawl surveys on the continental shelf of the eastern Bering Sea and 2) an increasing proportion of older and larger fish in the commercial catch from the continental slope of both the eastern Bering Sea and Aleutian Islands. The cause of the decline in recruitment could not be clearly identified.

Greenland turbot of the Bering Sea-Aleutian Islands share certain distributional features with the North Atlantic form. There is an apparent bathymetric change in the size and age of fish, with younger animals occupying continental shelf depths and the older individuals residing at depths of the continental slope. At shallow depths the young are exposed to temperature fluctuations, whereas older animals along the slope are exposed to relatively stable temperatures.

A hypothesis is proposed for describing the temporal and spatial paths by which young animals reach the mature or spawning portion of the population.

NOAA Technical Report NMFS 72. Penttila, Judy, and Louise M. Dery (editors). **"Age determination methods for northwest Atlantic species."** December 1988, iv + 135 p.

ABSTRACT

The successful application of techniques to enhance detection of age marks in biological specimens is of vital importance in fisheries research. This manual documents age determination techniques used by staff at the Woods Hole Laboratory, National Marine Fisheries Service. General information on procedures for preparing anatomical structures is described, together with criteria used to interpret growth patterns and assign ages. Annotated photographs of age structures are provided to illustrate criteria. Detailed procedures are given for the following species: Atlantic herring (*Clupea harengus*), haddock (*Melanogrammus aeglefinus*), Atlantic cod (*Gadus morhua*), pollock (*Pollachius virens*), silver hake (*Merluccius bilinearis*), red hake (*Urophycis chuss*), black sea bass (*Centropristis striata*), weakfish (*Cynoscion regalis*),

Atlantic mackerel (*Scomber scombrus*), butterfish (*Peprilus triacanthus*), redfish (*Sebastes fasciatus*), summer flounder (*Paralichthys dentatus*), winter flounder (*Pseudopleuronectes americanus*), witch flounder (*Glyptocephalus cynoglossus*), American plaice (*Hippoglossoides platessoides*), yellowtail flounder (*Limanda ferruginea*), surf clam (*Spisula solidissima*), and ocean quahog (*Arctica islandica*).

NOAA Technical Report NMFS 73. Vecchione, Michael, Clyde F.E. Roper, and Michael J. Sweeney. **"Marine flora and fauna of the eastern United States Mollusca: Cephalopoda."** February 1989, iii + 23 p., 29 figs.

ABSTRACT

The cephalopods found in neritic waters of the northeastern United States include myopsid and oegopsid squids, sepiolid squids, and octopods. A key with diagnostic illustrations is provided to aid in identification of the eleven species common in the neritic waters between Cape Hatteras and Nova Scotia; included also is information on two oceanic species that occur over the continental shelf in this area and that can be confused with similar-looking neritic species. Other sections comprise a glossary of taxonomic characters used for identification of these species, an annotated systematic checklist, and checklists of the 89 other oceanic species and 18 other Carolinian and subtropical neritic species that might occur occasionally off the northeastern United States.

NOAA Technical Report NMFS 74. Krzynowek, Judith, Jenny Murphy, Richard S. Maney, and Laurie S. Panunzio. **"Proximate composition and fatty acid and cholesterol content of 22 species of Northwest Atlantic finfish."** May 1989, iii + 35 p., 3 tables, 1 app.

ABSTRACT

The moisture, fat, ash, fatty acid profile, and cholesterol content are reported for cooked and raw fillets from 22 species of finfish found in the Northwest Atlantic. All but nine species had 1% or less fat. Ocean perch and a spring sampling of mackerel and wolffish had about 2% fat, followed by yellowfin tuna, whiting, silver hake, butterfish, and a summer sampling of mackerel and wolffish with a range of 3-7% fat. Herring had a range of 5-12% fat representing a winter sampling on the low end and summer sampling on the high end of the range. Bluefin tuna (a summer sampling) contained the most fat with a high of 23% fat. Omega-3 fatty acids were present in excess of omega-6 fatty acids. The fattier fish supplied the most omega-3 fatty acids per gram of tissue. The mean cholesterol content for all species was 57 + 16 mg/100 g raw tissue. Finfish from the Northwest Atlantic would appear to fit into the regime for a healthy heart, being low in fat and cholesterol and rich in omega-3 fatty acids.

NOAA Technical Report NMFS 75. Simpson, David G. **"Codend selection of winter flounder *Pseudopleuronectes americanus*."** March 1989, iii + 10 p., 5 figs., 5 tables.

ABSTRACT

Codend selection of winter flounder (*Pseudopleuronectes americanus*) in 76-127 mm mesh codends was examined from experiments conducted in Long Island Sound during the spring of 1986-87. The results show a slightly larger size at selection than was found in earlier work as indicated by the selection factor, 2.31 in the present study compared with 2.2 and 2.24 from previous studies. Diamond mesh was found to have a length at 50% retention about 1 cm longer (L_{50}=22.6 cm), and a selection range (3.4 cm) about 1 cm narrower, than square mesh in 102-mm codends. Tow duration varied from 1 to 2 hours using 114-mm diamond mesh. As has been found in previous studies, tow duration and L_{50} are positively related, with 1-hour tows averaging 24.6 cm and 2-hour tows averaging 26.6 cm. The importance of the slope of the selection curve was examined in yield-per-recruit analyses by comparing knife-edge and stepwise recruitment. In all mesh sizes, stepwise recruitment provides a more conservative estimate of yield in the presence of a minimum size limit. Differences in yield estimates between the two models were generally small (1-7%), except in the largest mesh size, 127 mm, where yield is overestimated by 10% when assuming knife-edge recruitment.

NOAA Technical Report NMFS 76. Love, Milton S., Jeffrey Stein, Robert H. Moore, Michael Mullin, John S. Stephens, Jr., Meenu Sandhu, and Kevin T. Herbison. **"An analysis of fish diversion efficiency and survivorship in the fish return system at San Onofre Nuclear Generating Station."** April 1989, iii + 16 p., 14 figs., 3 tables, 4 app.

ABSTRACT

This study examined the efficiency of fish diversion and survivorship of diverted fishes in the San Onofre Nuclear Generating Station Fish Return System in 1984 and 1985. Generally, fishes were diverted back to the ocean with high frequency, particularly in 1984. Most species were diverted at rates of 80% or more. Over 90% of the most abundant species, *Engraulis mordax*, were diverted. The system worked particularly well for strong-swimming forms such as *Paralabrax clathratus*, *Atherinopsis californiensis*, and *Xenistius californiensis*, and did not appreciably divert weaker-swimming species such as *Porichthys notatus*, *Heterostichus rostratus*, and *Syngnathus* sp. Return rates of some species were not as high in 1985 as in 1984. Individuals of most tested species survived both transit through the fish return system and 96 hours in a holding net. Some species, such as *E. mordax*, *X. californiensis*, and *Umbrina roncador*, experienced little or no mortality. Survivorship of Seriphus politus was highly variable and no *Anchoa delicatissima* survived.

Authors, Titles, and Subjects in the *Marine Fisheries Review* 51(1-4), 1989

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Papers in the *Marine Fisheries Review* 51(1-4), 1989

Editorial Guidelines for the *Marine Fisheries Review*

The *Marine Fisheries Review* publishes review articles, original research reports, significant progress reports, technical notes, and news articles on fisheries science, engineering, and economics, commercial and recreational fisheries, marine mammal studies, aquaculture, and U.S. and foreign fisheries developments. Emphasis, however, is on in-depth review articles and practical or applied aspects of marine fisheries rather than pure research.

Preferred paper length ranges from 4 to 12 printed pages (about 10-40 manuscript pages), although shorter and longer papers are sometimes accepted. Papers are normally printed within 4-6 months of acceptance. Publication is hastened when manuscripts conform to the following recommended guidelines.

The Manuscript

Submission of a manuscript to *Marine Fisheries Review* implies that the manuscript is the author's own work, has not been submitted for publication elsewhere, and is ready for publication as submitted. Commerce Department personnel should submit papers under a completed NOAA Form 25-700.

Manuscripts must be typed (double-spaced) on high-quality white bond paper and submitted with two duplicate (but not carbon) copies. The complete manuscript normally includes a title page, a short abstract (if needed), text, literature citations, tables, figure legends, footnotes, and the figures. The title page should carry the title and the name, department, institution or other affiliation, and complete address (plus current address if different) of the author(s). Manuscript pages should be numbered and have 1½-inch margins on all sides. Running heads are not used. An "Acknowledgments" section, if needed, may be placed at the end of the text. Use of appendices is discouraged.

Abstract and Headings

Keep titles, heading, subheadings, and the abstract short and clear. Abstracts should be short (one-half page or less) and double-spaced. Paper titles should be no longer than 60 characters; a four- to five-word (40 to 45 characters) title is ideal. Use heads sparingly, if at all. Heads should contain only 2-5 words; do not stack heads of different sizes.

Style

In style, the *Marine Fisheries Review* follows the "U.S. Government Printing Office Style Manual." Fish names follow the American Fisheries Society's Special Publication No. 12, "A List of Common and Scientific Names of Fishes from the United States and Canada," fourth edition, 1980. The "Merriam-Webster Third New International Dictionary" is used as the authority for correct spelling and word division. Only journal titles and scientific names (genera and species) should be italicized (underscored). Dates should be written as 3 November 1976. In text, literature is cited as Lynn and Reid (1968) or as (Lynn and Reid, 1968). Common abbreviations and symbols such as mm, m, g, ml, mg, and °C (without periods) may be used with numerals. Measurements are preferred in metric units; other equivalent units (i.e., fathoms, °F) may also be listed in parentheses.

Tables and Footnotes

Tables and footnotes should be typed separately and double-spaced. Tables should be numbered and referenced in text. Table headings and format should be consistent; do not use vertical rules.

Literature Cited

Title the list of references "Literature Cited" and include only published works or those actually in press. Citations must contain the complete title of the work, inclusive pagination, full journal title, and the year, month, volume, and issue numbers of the publication. Unpublished reports or manuscripts and personal communications must be footnoted. Include the title, author, pagination of the manuscript or report, and the address where it is on file. For personal communications, list the name, affiliation, and address of the communicator.

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Authors must double-check all literature cited; they alone are responsible for its accuracy.

Figures

All figures should be clearly identified with the author's name and figure number, if used. Figure legends should be brief and a copy may be taped to the back of the figure. Figures may or may not be numbered. Do not write on the back of photographs. Photographs should be black and white, 8 × 10 inches, sharply focused glossies of strong contrast. Potential cover photos are welcome, but their return cannot be guaranteed. Magnification listed for photomicrographs must match the figure submitted (a scale bar may be preferred).

Line art should be drawn with black India ink on white paper. Design, symbols, and lettering should be neat, legible, and simple. Avoid freehand lettering and heavy lettering and shading that could fill in when the figure is reduced. Consider column and page sizes when designing figures.

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First-rate, professional papers are neat, accurate, and complete. Authors should proofread the manuscript for typographical errors and double-check its contents and appearance before submission. Mail the manuscript flat, first-class mail, to: Editor, *Marine Fisheries Review*, Scientific Publications Office, National Marine Fisheries Service, NOAA, 7600 Sand Point Way N.E., Bin C15700, Seattle, WA 98115.

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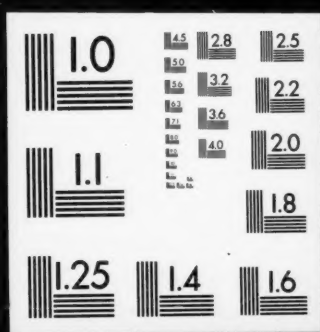
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